Lake Okeechobee Phosphorus Removal Demonstration

Final Report
March 2019

PHOSPHORUS FREE WATER SOLUTIONS

Submitted to:
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, Florida 33406

sfwmd.gov

Abstract

This report is furnished pursuant to a purchase request from the South Florida Water Management District under the Governors "State of Emergency" Executive Orders: - 2018-191 and 2018-249. The scope of the project provided for demonstration of Phosphorus Free Water Solutions novel phosphorus removal technology as a means of reducing nutrients available to feed toxic algae. Further, the scope provided for a relative comparison of the projected operating costs for this technology operating at full scale under a specific set of conditions provided by SFWMD. It is not intended for this report to comprise a specific "proposal" in the commercial sense, but rather to document a demonstration of the technology and to provide a basis on which the technology could be compared to previously evaluated technologies.

The Phosphorus Free business model is an important consideration when evaluating this report because it is significantly different than most projects conducted by SFWMD. Phosphorus Free provides:

a. Strictly Pay for Performance – third party verified nutrient removal
b. All construction and operating capital
c. Manages the permitting and construction process
d. Operating personnel and operates the facility
e. All operating and maintenance costs

This demonstration documents the achievement of phosphorus removal to 33 µg/L TP and 21 µg/L Dissolved Phosphorus in treated water samples from the primary lake outflow canals and the lake itself. Also documented are the projected benefits of deployment of a single regional facility under the Pay for Performance model which indicate that approximately 200 metric tons of phosphorus can be removed annually under the treatment scenario modeled for this project. This represents removal of 20% to 50% of the phosphorus in excess of the Lake Okeechobee TMDL established by the FDEP.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

CFS	Cubic feet per second
EPA	Environmental Protection Agency
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
LOD	Limit of detection
LOQ	Limit of quantitation
MDL	Minimum detection limit
µg/l	Units of concentration, parts per billion
mg/l	Units of concentration, parts per million
MT	Metric tons
NELAC	National Environmental Laboratory Accreditation Program
ND	Not Determined
nm	Nanometer
NTU	Units of turbidity, nephelometric turbidity unit
PFWS	Phosphorus Free Water Solutions
PT-Co Units	Platinum cobalt units - Units of Color
QA	Quality Assurance
SCADA	Supervisory Control and Data Access
TMDL	Total maximum daily loads
TN	Total nitrogen
TP	Total phosphorus
USGS	United States Geological Survey
µS/cm	Unit of conductivity, micro Siemens per centimeter

EXECUTIVE SUMMARY

INTRODUCTION

Phosphorus Free Water Solutions ("PFWS"), was retained by the South Florida Water Management District ("SFWMD or District") under the Governors "State of Emergency", Executive Orders 2018-191 and 2018-249 and in accordance with a SFWMD purchase order 4500109726 ("PO") to conduct a demonstration of novel, new technology for the removal of Total and Dissolved Phosphorus from surface water. The Project Scope provided for demonstration of Phosphorus Free Water Solutions novel phosphorus removal technology along with certain core deliverables including a comparative economic analysis for a full scale deployment of the demonstrated technology.

- **Treat and Report Treatment Results.** Treat Various selected water channel flows in the Lake Okeechobee watershed for removal of total phosphorus utilizing PFWS's proprietary treatment technologies and report on the efficacy for phosphorus removal together with any post treatment water quality changes.
- **Report on Factors that Influence Pricing Optimization in a Commercial Facility.** It is noted the SOW formally calls for advising on pricing matters for phosphorus removal at demonstration flow levels. However, SFWMD has agreed the intent is to receive direction on potential cost and economic matters assuming installation of a full-scale commercial facility. Additionally, as the project unfolded a third, informal objective emerged, that being to provide commentary as to how PFWS's phosphorus removal technologies could be deployed in a manner that not only optimizes price and performance but also result as a materially positive and timely impact on the flow of excess phosphorus into Lake Okeechobee. This is in keeping with the recent directive of the Governor DeSantis to explore, prioritize and implement technologies and projects that provide the **'Largest, and Most Meaningful impact on Nutrient Removal'** and the reduction of Lake Okeechobee discharges to the coastal estuaries.
- **Commercial Proposal.** It is not intended for this report to comprise a specific "proposal" in the commercial sense, but rather to document a demonstration of the technology and to provide a basis on which the technology and economics could be compared to previously evaluated technologies.
- **Business Model.** Understanding the Phosphorus Free business model is an important consideration when evaluating this report because it is decidedly different than most projects managed by the district. Phosphorus Free provides:

    a. All construction and operating capital
    b. Manages the permitting and construction process
    c. Operating personnel and operates the facility
    d. All operating and maintenance costs

e. Phosphorus Free is only compensated for third party verified removal of phosphorus and/or nitrogen at a contractually agree upon rate per pound.
f. There is no upfront cost to SFWMD.

ECONOMIC SUMMARY

a. For the modeled concept, PFWS will invest $80MM – $100MM to construct and operate removal facilities in the Lake Okeechobee watershed
b. Projected removal cost would start at approximately $175 per pound and fall progressively to about $100 per pound by year 10.
c. Under the PFWS business model, the contractor would only receive payment for third party verified pounds of phosphorus, nitrogen or combined nutrients removed.
d. The price falls over time as economies of scale are realized, treatment volumes are increased, personnel cost is spread over a greater volume and capital is recovered.
e. Represents a savings of approximately $100MM annually compared to traditional methodology.

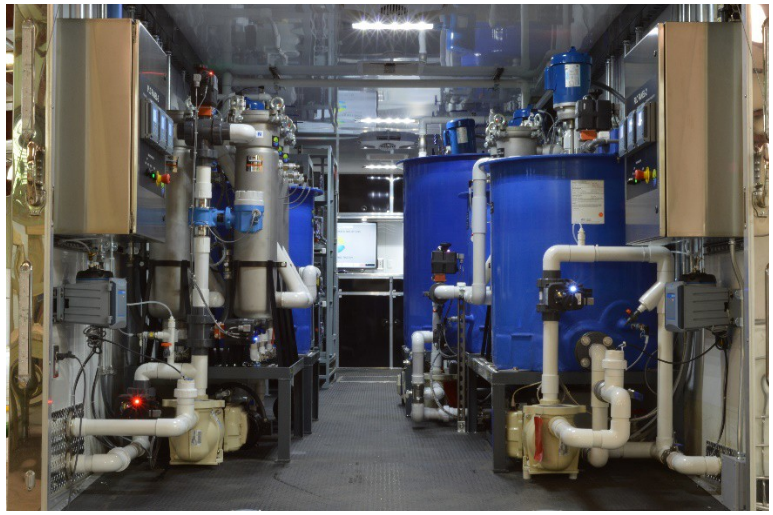
TECHNOLOGY PLATFORM DEPLOYED

PFWS utilized its proprietary, patent pending technology platform in conducting the demonstration trial. PFWS technologies include various methods and chemical compounds which as deployed in PFWS's nutrient removal processes DO NOT create any toxic or harmful by-products and COMPLY with the requirements of Class III Water Standards[1]. PFWS continues to invest in and advance its technology platform in an effort to improve processing efficacy, efficiency including the reduction or elimination of processing steps and chemical compositions. Detailed discussion of PFWS' confidential and proprietary technologies deployed during the trial is reserved for the CONFIDENTIAL SECTION of this report.

The demonstration equipment deployed for this testing program is essentially a rolling laboratory in which various process configurations can be simulated and monitored. This equipment serves as a development platform, is highly instrumented and monitored using a state-of-the-art SCADA system to monitor and record process performance.

[1] FAC-Ch 62-302 – Florida Water Quality Standards (2010). https://www.flrules.org/gateway/ChapterHome.asp?Chapter=62-302

Photograph 1 and 2: Demonstration Equipment looking back to front (PFWS Internal Photo)



PERFORMANCE RESULTS AND KEY SUPPORTING CONCLUSIONS

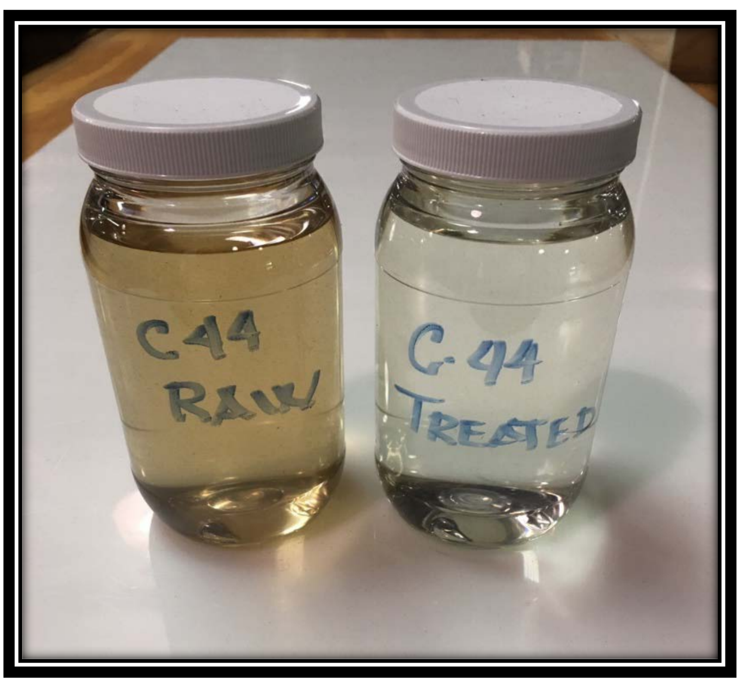
Testing was conducted over approximately 10 weeks at 4 selected locations in the Lake Okeechobee Watershed. The following table (Table 1) summarizes the performance at each location and below is additional commentary analysis. The results support and are consistent with performance findings conducted with other water management districts.

- PFWS successfully demonstrated removal of dissolved and total phosphorus to very low levels, 21 and 33 µg/L respectively (excluding S-191 Canal), well below established concentration based TMDL's which tend to be set at about 50 µg/L. It is important to note that regardless of the inflow concentration of phosphorus, PFWS processes will achieve the de minimis levels of outflow concentration reflected in this report even if inflow phosphorus concentration is orders of magnitude greater.
- Background or iron concentration in the incoming water was reduced by approximately 70% in the treated outflow (See Table 18).
- Water color was reduced by about 50% when compared with inflow color (See Table 18).
- Total Nitrogen was reduced by about 30% compared to untreated samples (See Table 18).

Table 1: Average Site Performance Summary

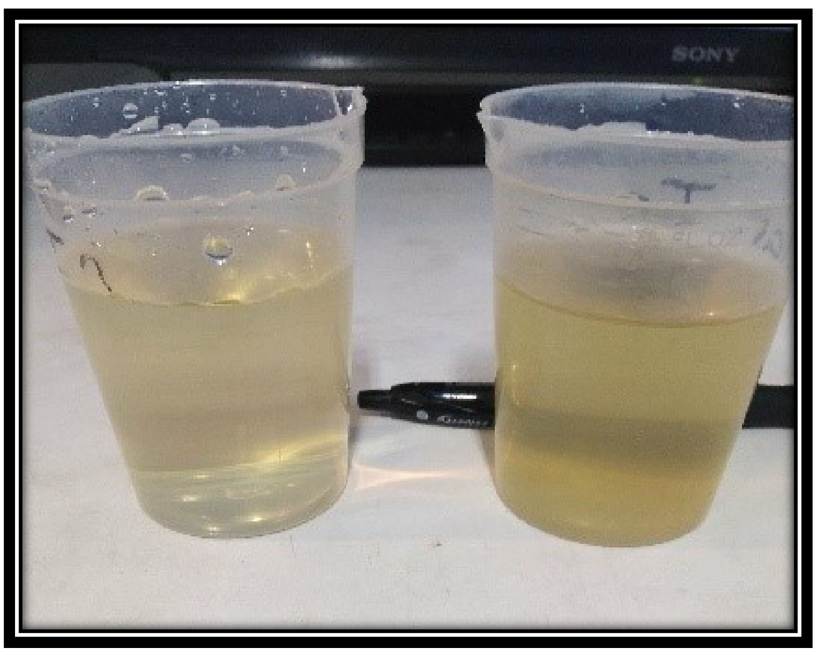
Location	TP Inflow µg/l	TP Outflow µg/l	Diss. P Inflow µg/l	Diss P Outflow µg/l	TN Inflow mg/l	TN Outflow mg/l
Location 1 – DuPuis	116	25	41	25	1.27	0.95
Location 2 – LaBelle	86	28	37	14	1.7	1.50
Location 3 – S-191 Canal	209	125	177	95	1.51	1.44
Location 4 – Lake Okeechobee NE	128	44	37	25	1.47	1.15

The following photographs (Photograph 3-6) represent water samples taken during routine operation at the various demonstrations sites and show the water clarity before and after the treatment process representing typical results at each location. As depicted in the photographs, the treated water exhibited a significant color reduction resulting from oxidation and removal of soluble organic (lignin and tannin) compounds.



Photograph 3 - C-44 – DuPuis Management Area (PFWS Internal Photo)

Photograph 4 - C-43 – LaBelle Riverfront Park (PFWS Internal Photo)



Photograph 5 - S-191 Canal (PFWS Internal Photo)

Photograph 6 - Lake Okeechobee – NE – S191 Area (PFWS Internal Photo)

PHOSPHORUS REMOVAL VALIDATION

Phosphorus removal was validated through several independent processes, including split sampling, where a sample was collected and then split into three containers. Each of the testing parties (SFWMD, third-party, and PFWS Lakeland) received an identical sample. The SFWMD laboratory analyzed one of the samples, the third-party laboratory another sample and the final sample was analyzed at the PFWS Lakeland laboratory. Additional third-party analysis and routine PFWS Lakeland sample collection and analysis were also performed. Further, a validation study was conducted to compare PFWS Lakeland analytical performance with that of the third-party laboratory.

DISCUSSION

This demonstration project took place during November – December 2018 and January 2019 at the locations noted below. During testing at these locations, the Lake Okeechobee discharge gates were closed so the water in the canals withdrawn for treatment was essentially basin flow and was somewhat lower in phosphorus than has been historically noted during discharge periods.

Average treated water phosphorus values of about 21 µg/L dissolved and about 33 µg/L total P were achieved. Nitrogen was reduced by as much as 30% in the process version tested at these locations. The inflow water contained between 70 and 200 µg/L total P, 60 to 140 µg/L dissolved P and 1 to 2 mg/L of total N. The PFWS process does not simply remove a percentage of the inbound phosphorus. Regardless of the inbound concentration of phosphorus, the process will remove it to the minimal levels cited herein. While incoming phosphorus concentrations during this study period were relatively low at less than 200 µg/L, previous work at Lake Apopka documents removal to the same approximate concentrations when receiving as much as 1400 µg/L. [2]

The testing locations were collectively selected by both SFWMD and PFWS personnel and were identified as follows: (1) The C-44 Canal near the DuPuis Management Area, (2) The C-43 Canal near LaBelle, (3) The upstream canal at S-191, and (4) Lake Okeechobee near the S-191 Structure. Treatment at C-43, C-44 and the Lake itself demonstrated successful removal of dissolved and total phosphorus as well as a significant reduction of nitrogen whereas performance at the S-191 location, while demonstrating removal of phosphorus, did not demonstrate removal to the same low levels as the other 3 locations.

Location S-191 Canal, a location that had been stagnant for approximately several months prior to testing, proved somewhat challenging and while significant reduction of both phosphorus species was demonstrated, the removal effectiveness at this location was lower compared to the other locations. It is theorized that this location might contain higher than normal levels of residual surfactants because the water exhibited behavior characteristic of high levels of detergent (surfactant) as it generated substantial amounts of froth and foam unlike the other locations. Numerous factors can account for foaming and surfactants are merely one possibility. It is also possible that this water contained a higher fraction of highly polymerized organic phosphates and the oxidation process required a longer reaction time than was available. Samples have been submitted for detailed analysis to evaluate for unknown constituents and determine a remedy should this phenomenon resurface. Except for one short duration excursion at S-191, all treated water met or exceeded Class III Water Standards[1]. During the excursion period at S-191, conductivity exceeded Class III Water Standards[1] for a brief period.

Previously, PFWS demonstrated the use of an iron-based oxidant to facilitate the release of reactive phosphorus from various bound forms. This oxidant increased the iron residual in the treated water somewhat yet remained below the Class III limitation for iron. The previous process utilized the iron-based oxidant as part of the pre-treatment process prior to subsequent phosphorus removal as a calcium compound. The water locations utilized in this study however, contained somewhat higher levels of soluble reactive phosphorus than previous demonstration sites and as such, the process demonstrated during this study did not require the use of an iron-based oxidation step to achieve the phosphorus reduction results reported herein. As the results indicate, background iron in the water at the locations tested was reduced by as much as 70% (See Table 18).

[2] Phosphorus Free Water Solutions. (2017). Lake Apopka Dredging, Spoil Management and Water Treatment Project Final Report-Contract 28028.

FINANCIAL ANALYSIS DISCUSSION

The SOW seeks guidance from PFWS as to operational factors and constraints that will influence price and overall cost as expressed in units of benefit, price per pound of phosphorus removed. However, any discussion of these issues is predicated on an understanding of the PFWS business model. PFWS business model is solely PAY FOR PERFORMANCE. PFWS assumes all risk and bears all (100%) cost of facility capital construction and operating costs. The only payment PFWS receives is a contractually agreed price per pound of nutrient removed as verified by an independent third-party laboratory. PFWS business and operating model represents a paradigm shift from conventional funding and operating methods and programs directed at remediating excess phosphorus. The PFWS model is differentiated with the following features each of which has a material impact on reducing total nutrient removal cost:

- **Dynamic Treatment Facility Design to fit virtually any site configuration**
- **Variable (flexible) operating capability – 100 CFS Design can be operated at about 6-8 CFS to accommodate seasonal variation and rainfall driven events**
- **Financing – PFWS provides all project financing**
- **Pay for Performance – No payment until removal is documented**
- **Third Party Verified and Scientifically Confirmed Results.**
- **Timeline to Treatment Impact – 10 months - permit to operation time frame**
- **"Largest and Most Meaningful Impact on Nutrient Removal"**

REGIONAL CONCEPT EXAMPLE AND ECONOMIC SUMMARY

An additional project deliverable was the preparation of a Conceptual or Example Economic Analysis to demonstrate how this technology would compare to other phosphorus removal methods at a projected treatment volume which could be applied programmatically by SFWMD. After discussions with SFWMD personnel, one such analysis was prepared using information provided by SFWMD (2019 South Florida Environmental Report[3]). The data from Table 8B-3 in the referenced report indicates for the Taylor Creek Sub- Watershed, that WY 2018 annual average flows are 350 CFS and the WY average TP is 593 µg/L. From this information, PWFS developed a conceptual "regional project" based on these conditions for economic comparison to other documented cost evaluations of phosphorus removal methods. Further, the selection of these conditions does not imply that a single location is the only means of achieving the net beneficial impact of the concept. For this watershed, it is likely that multiple sites would be more effective under the current water distribution scenario. It is important to note that PFWS recognizes the variability in water flows thorough out the system and prior to making a formal proposal for service PFWS would consult with the district in determining the most appropriate location and

[3] South Florida Water Management District. (2019). *2019 South Florida Environmental Report.* https://www.sfwmd.gov/science-data/scientific-publications-sfer

size of facility. Further, while this analysis is prepared for a "regional and as yet undetermined location", this approach could be applied effectively at several strategic locations in the northern watersheds selected depending on the desired disposition of the treated water. The facilities, due to their parallel operating units have, by design, tremendous turn down capability without economic penalty. This enables PFWS treatment capacity to fluctuate to meet the incoming water requirements. Equally important, the facilities will be designed to accommodate approximately 75th percentile flows for a given location which means that during extremely high-water events like hurricanes or 100-year storm events, some of the water and associated nutrients will bypass the treatment facilities.

The basis of the comparative economic evaluation is intended to be a location or group of locations within the same watershed, north of the Lake with an average annual flow of 350 CFS and an average total phosphorus of 0.583 mg/L. These conditions, referred to as a "Regional Concept" are merely intended to create a scope or treatment volume concept that could be applied "programmatically" or on a watershed wide basis. This location could be anywhere where similar conditions exist and can be upsized or downsized accordingly to fit almost any specific site configuration or flow and concentration conditions.

The concept described above is effectively a regional (rather than targeted hot spot locations) approach to nutrient reduction. The basis of this concept is that PFWS, at its own expense, would construct an initial 50 CFS facility. This initial facility size was chosen because PFWS is currently under contract to the SJRWMD for a 16.75 CFS facility which will be operational in mid to late 2019. A 50 CFS facility would simply be 3 parallel trains of treatment capacity, each substantially similar to the SJRWMD facility which represents a 3x scale up over what will be an existing commercial scale facility at Lake Apopka.

Once the first facility is operational PFWS would then sequentially construct, additional facilities of an appropriate size up to approximately 100 CFS each (2x scale-up) to bring the total treatment capacity to 350 CFS or the ultimate treatment capacity determined by analysis of a specific site location. This approach can be replicated for other areas where such a regional approach would be beneficial. Subsequent facilities do not have to be co-located with the initial facility. For a scenario of this scope, PFWS would ultimately invest approximately $80MM - $100MM in construction capital.

Initial estimates are that the initial 50 CFS facility would remove approximately 62,000 lb. of phosphorus and 27,000 lb. of nitrogen annually, and progress, as additional capacity is added, to approximately 433,000 lb. phosphorus and 200,000 lb. nitrogen on an annual basis.

Projected costs for removal would start at approximately $175 per pound and fall progressively to about $100 per pound by year 10. Under the PFWS business model, the contractor would only receive payment for third party verified pounds of phosphorus, nitrogen or combined nutrients removed. The price falls over time as economies of scale are realized, treatment volumes are increased, personnel cost is spread over a greater volume and capital is recovered.

PFWS will contractually commit to these price reductions. At full implementation, this approach would represent a savings of $100MM or more annually compared to traditional removal methodology.

As a comparison to existing phosphorus removal methodologies, the University of Florida, IFAS[4], in 2004 prepared an analysis of many (12) treatment methodologies and arrived at a 50-year discounted average cost, which is the standard evaluation method prescribed by the Army Corps of Engineers, for each of the treatment options. The average of these costs was $247.07 (discounted 2004 dollars) per pound. Escalating (Bureau of Labor Statistics methodology) this cost to 2017 dollars results in an estimated cost of $320.15 (discounted 2017 dollars) per pound. The PWFS non-discounted costs are calculated using the same categories of costs and credits as the ACOE methodology utilized in the reference study. By comparison, and based on the UF analysis, traditional facilities with an equivalent removal capacity to that proposed above, utilizing currently practiced methodologies, would require a land area in excess of 5000 acres[a], a capital investment by the state of about $80MM[b] and carry an average annual cost in excess of $200MM[c].

a. From Table 2 in the 2004, IFAS Economic Analysis of Water Treatments for Phosphorus Removal, the average number of pounds of phosphorus removed per acre is 80 pounds. An area removing 420,000 pounds of phosphorus annually would require 5250 Acres.
b. From Table 2 in the note 1 reference, the average discounted spending for Capital Cost was $72.68M for an average size of 4993 Acres resulting in an average discounted cost per acre of $14,562. For the 5250 Acres noted in 1 above, the estimated discounted cost would be $76.45MM (2004$) and which is approximately equivalent to $99MM (discounted 2017$).
c. From Table 2 in the note 1 reference, the average cost of removal is $247.07 per pound including a 50% cost share from outside the state. For 420,000 pounds of phosphorus, this equals $207.5MM annually (discounted 2004$) and $268.5MM annually (discounted 2017$). A Federal cost share may reduce this amount but would similarly reduce the costs of the PFWS treatment.

(All costs cited from the note 1 reference include the credits for water supply, recreation and non-phosphorus removal benefits cited therein.)

OTHER CONSIDERATIONS

While the above discussion and that in latter sections reference a “Regional Concept”, the specific intent of the discussion and economic comparison is to provide a frame of reference to compare the PFWS phosphorus removal process with other removal methods of similar scale. The specific location attributes of the potential project are not a critical component of the economic analysis.

[4] Sano, D., Hodges, A., & Degner, R. (2005, November). Economic Analysis of Water Treatments for Phosphorus Removal in Florida. *UF/IFAS Food and Resource Economics Department, FE* (576).

The availability of land required for such a regional nutrient removal facility is an additional consideration. PFWS estimates that approximately 50 acres would be required for a single co-located facility treating 350 CFS, but the individual components, for a 50 CFS would only be 2-3 acres, while a 100 CFS facility would require about 5-6 acres. The PFWS equipment is very modular and can be configured in numerous ways to accommodate a wide variety of site configurations.

Finally, PFWS was asked to make a specific recommendation for a facility that resulted in the lowest cost per pound of phosphorus removed. Facility size is truly a site-specific determination relying on the history of flows and concentrations at a given location. Statistical models are utilized to assist in facility size determinations. In the confidential document section of this report, PFWS has outlined a specific strategy for a Regional Concept. In general, however, treatment costs are inversely proportional to the phosphorus concentration, that is, the higher the phosphorus concentration, the lower the unit cost of treatment. Further, under the PFWS model, the removal cost will be contractually specified.

The geographic distribution of phosphorus over the Northern Okeechobee watersheds lends itself to two distinct and complimentary approaches. First, the regional approach described above, and second, a more targeted, site specific approach where isolated locations have relatively high phosphorus concentrations and lower flows. These locations may fall more in the province of FDACS and might require landowner partnerships to facilitate treatment at these isolated locations.

This approach along with a detailed process description is outlined in greater detail in a separate and confidential section of this report. The information contained in this section titled **Economic Analysis - Potential Application Sites** is exempt from the State of Florida Public Records Act pursuant to **FS 812.081**, and **FS 815.045** respectively. Accordingly, PFWS requests Confidential Treatment for all Process information identified herein as Confidential or Confidential Trade Secret. PFWS has undertaken a thorough review of The Process to minimize the scope of information requiring Confidential Treatment

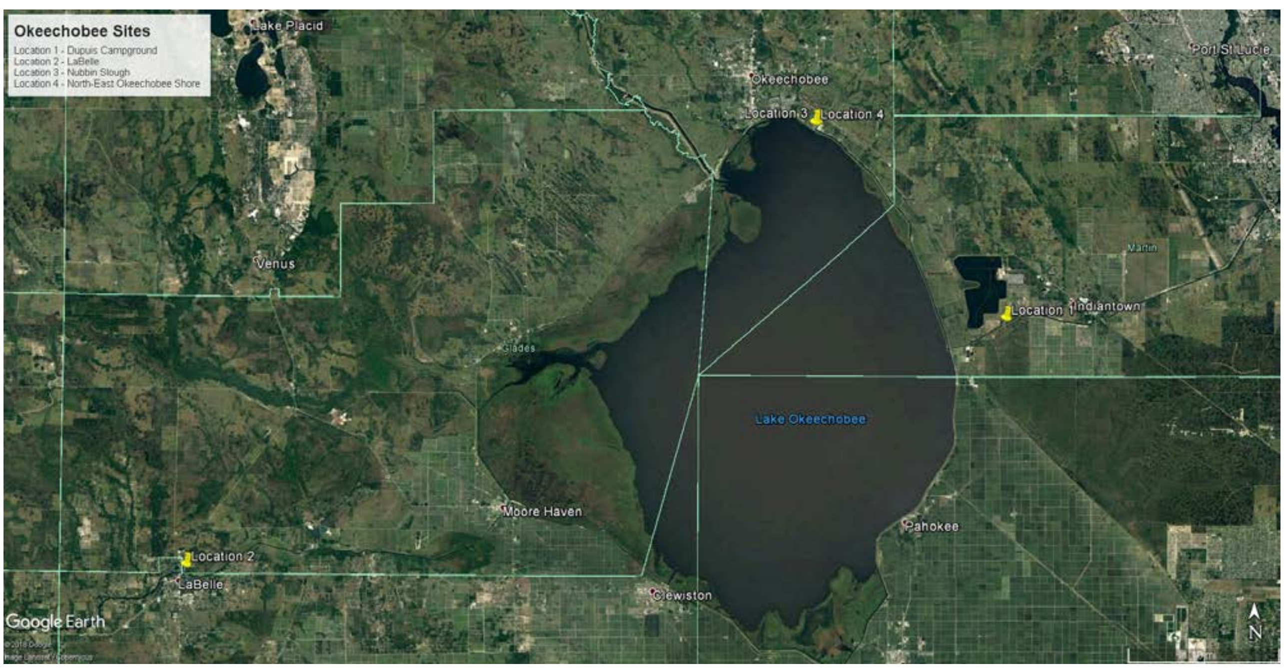
As part of the review of this report and this demonstration, SFWMD conducted a review of this report and asked many questions. Those comments, questions and answers where appropriate, will be provided as a report supplement subsequent to the issue of this report.

Testing and Sample Locations

- **DuPuis (C-44 Adjacent to DuPuis Campground)** GPS: 27°0’24.978”N 80°33’38.455”W
- **LaBelle (C-43 At LaBelle River Park)** GPS: 26°46’11.921”N 81°25”59.456”W
- **S-191 Canal (Canal C-59)** GPS: 27°11”37.02”N 80°45’42.761”W
- **Lake Okeechobee – NE** GPS: 27°11’32.37”N 80°45’52.018”W

For this demonstration, three locations were initially chosen to validate the capability of the process. The first two (canal C-44 adjacent to the DuPuis campground facility and canal C-43 at LaBelle River Park), were selected before mobilizing. The third, S-191 on canal C-59 at Lake Okeechobee, was selected during the trial period at the other sites. Multiple sites were evaluated, and preliminary site evaluation determined S-191 to be a location where the layout was suitable, and levels of phosphorus were somewhat higher than in the C-43 and C-44 canals. However, after arriving on site and beginning operations the canal was noted to be stagnant (no flow through the S-191 structure) and turbidity curtains were present as part of an ongoing construction project. Communication with SFWMD determined that the location had been stagnant since about August of 2018 and was determined to be non-representative of water that would normally be encountered at this location. As such and given the proximity of direct access to Lake Okeechobee itself, PFWS, with SFWMD’s agreement, and at no additional cost, elected to add testing on existing lake water as a fourth location.

Figure 1 – Lake Okeechobee Overall Treatment Location Map



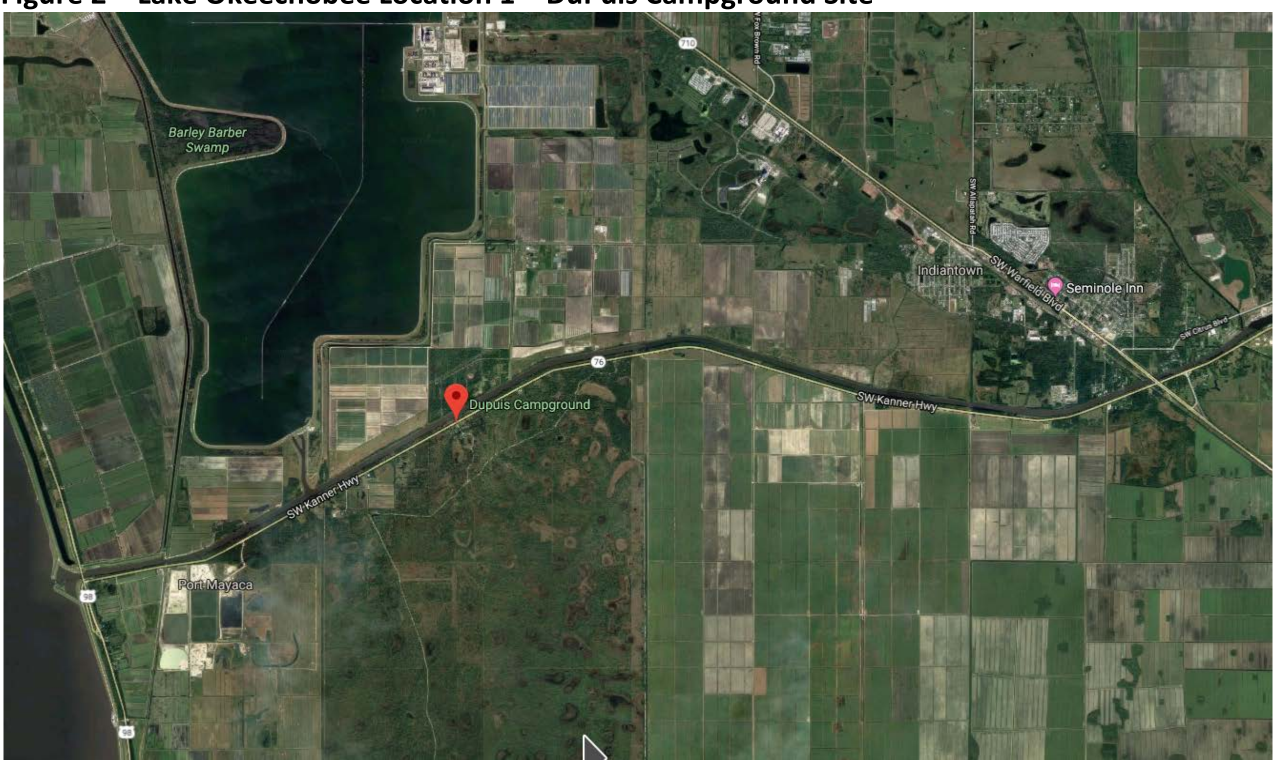
DuPuis (C-44 Adjacent to DuPuis Campground) GPS: 27°0’24.978” N 80°33’38.455”W

The first location for process testing was the Canal C-44 (Figure 2) that flows into Port St Lucie. The location was adjacent to the Dupuis Campground located in the DuPuis Management area.

The demonstration equipment was deployed on a cleared section of the embankment overlooking the canal. Hose was connected from the inlet of the process trailer and dropped over the embankment. The overall length of the hose was approximately 25ft and vertical drop of the embankment was about 16ft. The inlet of the hose was submerged and suspended at depth of approximately six inches using a floating suction device that ensured minimal silt or sediment was entrained. The treated outflow discharged directly into the canal through a hose which was located downstream from the suction hose.

Operations in DuPuis commenced on November 7th of 2018 and ran for 14 days until the 21st of November.

Figure 2 – Lake Okeechobee Location 1 – DuPuis Campground Site



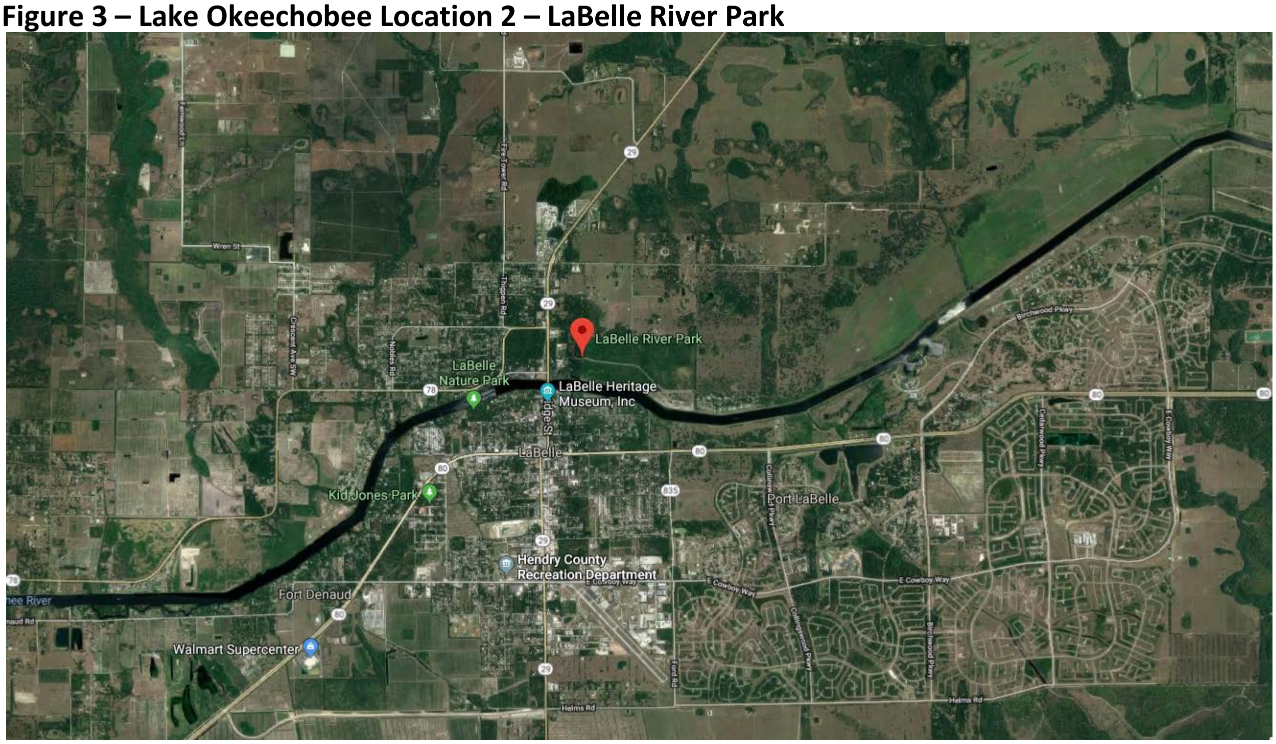
LaBelle (C-43 At LaBelle River Park) GPS: 26°46’11.921”N 81°25”59.456”W

The second location for process testing was the C-43 Canal (Figure 3) that flows west from the Lake. The specific location was at the LaBelle River Park.

The demonstration equipment was deployed on a cleared section of the embankment overlooking the canal. Hose was connected from the inlet of the process trailer and dropped over the embankment. The overall length of the hose was approximately 25ft and vertical drop of the embankment was about 14ft. The inlet of the hose was submerged and suspended at depth of approximately six inches using a floating suction device that ensured minimal silt or sediment was entrained. The treated outflow discharged directly into the canal through a hose which was located downstream from the suction hose.

Operations in LaBelle commenced on November 24th of 2018 and ran for 15 days until December 9th.

Figure 3 – Lake Okeechobee Location 2 – LaBelle River Park



S-191 Canal (Canal C-59) GPS: 27°11”37.02”N 80°45’42.761”W

The third location for process testing was near Structure S-191 in canal C-59 (Figure 4). The location was next to US-441 on the south. The trailers were set up on the northwest side of the canal.

The demonstration equipment was deployed on a grassy shoulder next to the embankment of the canal. Hose was connected from the inlet of the process trailer and dropped over the embankment. The overall length of the hose was approximately 20ft and slope of the embankment had a drop of about 8ft. The inlet of the hose was submerged and suspended at depth of approximately six inches using a floating suction device that ensured minimal silt or sediment was entrained. The treated outflow was discharged through a hose located downstream of the suction device.

Operations at S-191 commenced on December 10th of 2018 and ran for 10 days until December 20th.

Figure 4 – Lake Okeechobee Location 3 – S-191 Canal Side

Lake Okeechobee – NE GPS: 27°11’32.37”N 80°45’52.018”W

The fourth location for process testing was on the opposite side of the Herbert Hoover dyke to the northwest of structure S-191 (Figure 5).

The demonstration equipment was deployed on the gravel lot overlooking the northeast side of Lake Okeechobee. Hose was connected from the inlet of the process trailer and dropped over the embankment. The overall length of the hose was approximately 70ft and slope of the embankment had a drop of about 25ft. The inlet of the hose was submerged and suspended at depth of approximately six inches using a floating suction device that ensured minimal silt or sediment was entrained. The treated outflow was returned to the lake through a hose that was located a sufficient distance from the suction location to avoid recycling treated water.

Operations at Lake Okeechobee -NE commenced on December 26th of 2018 and ran for 15 days until January 13th of 2019 (Note: Operations were down for New Year’s Eve and New Year’s Day).

Figure 5- Lake Okeechobee Location 4 – S-191 – Lake Side

Methods

Samples were collected periodically from the inflow and the outflow to monitor process performance. The samples were tested for key water quality parameters. Both PFWS Lakeland and third-party laboratory testing were utilized to ensure the process was operating in accordance with its setpoints. The facility operated 24/7 and periodic PFWS Lakeland testing was utilized to monitor performance. The chosen PFWS Lakeland methods were selected based on factors such as short analysis time, ability to be performed in the field, and testing accuracy. This allowed for the closest to real time monitoring of process performance. Throughout the demonstration period at all locations, samples were collected and shipped to a third-party laboratory to validate analytical performance of the field laboratory. This testing was part of the PFWS routine quality program to ensure data integrity.

PFWS Lakeland

Phosphorus Free Water Solutions is not NELAC accredited and does not hold any certifications for performance of the methodologies presented below for the PFWS Lakeland laboratory. However, PFWS technicians are experienced in NELAC accredited facilities and understand the requirements of accredited facilities. To the greatest extent possible, PFWS laboratory practices mirror those of a NELAC laboratory. With the exceptions noted below, laboratory practices incorporate and follow the same Standard Methods, EPA methods, and FDEP protocols as the independent NELAC certified laboratories.

PFWS Lakeland data was utilized to monitor process performance in near real time to ensure compliance with process setpoint parameters and to create an historical archive of performance data. The frequency of testing was established to ensure that process related variances could be corrected as quickly as possible.

To ensure data integrity, PFWS periodically and throughout the study period validated the PFWS Lakeland laboratory performance through multiple third-party sample submissions and analysis of split samples that were submitted to the NELAC certified third-party laboratory that provided analytical services for this project.

Quality control for PFWS Lakeland analytical operation was consisted of routine validation and comparison with third party results, daily calibration of field and laboratory instruments, repeated analysis of standards, blanks and unknown samples. Standards were used to verify instrument calibration. Field instruments were routinely calibrated, and standards utilized for verification of the process instrumentation.

Table 2: Chemical analytes collected during this demonstration

Analyte	Methodology	Units
Alkalinity	Standard Methods SM2320B[5]	mg/L as $CaCO_3$
Color	Standard Methods SM2120C[6]	Units*
Conductivity	FDEP FT1200[7]	µS/*cm*
Total Iron	USEPA FerroVer[8]	mg/L
pH	FDEP FT1100[9]	mg/L
Dissolved Phosphorus	EPA 365.1 Compatible[10]	mg/L
Total Phosphorus	EPA 365.1 Compatible[10]	mg/L
Temperature	FDEP FT1400[11]	°C
Total Nitrogen	USGS Alkaline Persulfate[12]	mg/L
Turbidity	FDEP FT1600[13]	NTU

*SFWMD and third-party total iron samples were preserved with nitric acid

Sample Collection

Samples were collected in HDPE sample bottles and PP sampling cups. Before collection, the operator/technician would flush the sample port to ensure an accurate sample. Samples collected in sample bottles for the different analytes were preserved as listed in Table 3 below. For all collection points conductivity, pH, temperature, and turbidity were analyzed at the time of collection. If samples were immediately tested for total phosphorus, dissolved phosphorus, total nitrogen, total iron, alkalinity, or color at the time of sample collection then preservation was not performed for the sample tested. Regardless of whether the sample was immediately tested, a portion of the collected sample was poured into two sample bottles to be retained for later testing if needed. One sample bottle was treated with H_2SO_4 and the other did not receive any acid. All sample bottles were then stored on ice for transport until they could be placed in a refrigerator at 4°C or ready for analysis. It should be noted that the preservation methods did differ between PFWS, SFWMD, and the third-party lab. This was due to different analytical

[5] E.W. Rice, R.B. Baird, A.D. Eaton, Standard Methods for the Examination of Water and Wastewater(Online) 2320B Alkalinity Titration Method pp1-3
[6] E.W. Rice, R.B. Baird, A.D. Eaton, Standard Methods for the Examination of Water and Wastewater(Online) 2120 Color pp2-1 - 2-7
[7] FDEP, FT 1200 Field Measurement of Specific Conductance (Conductivity) 2017
[8] Hach, USEPA FerroVer Method, Total Iron Hach Method 8008 DOC316.53.01053 pp1-7
[9] FDEP, FT 1100 Field Measurement of Hydrogen Ion Activity (pH) 2017
[10] EPA Method 365.1, Revision 2.0: Determination of Phosphorus by Semi-Automated Colorimetry, 1993
[11] FDEP, FT 1400 Field Measurement of Temperature 2017
[12] USGS, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Evaluation of Alkaline Persulfate Digestion as an Alternative to Kjeldahl Digestion for Determination of Total and Dissolved Nitrogen and Phosphorus in Water, Water-Resources Investigations Report 03-4174 2003 pp 1-33
[13] FDEP, FT 1600 Field Measurement of Turbidity 2017

testing methods for total iron. Specifically, the third-party lab utilized EPA 200.7[14] which utilized nitric acid for the preservation agent. SFWMD also used nitric acid for preservation for total iron.

Table 3: Preservation methods for collected samples

Preservation Method	Analyte	Method
2-6°C	Alkalinity	SM2320B[5]
2-6°C	Color	SM2120C[6]
2-6°C, H_2SO_4, pH <2*	Total Iron	USEPA FerroVer[8]
2-6°C, H_2SO_4, pH <2	Total Phosphorus	EPA 365.1 Compatible[10]
2-6°C, H_2SO_4, pH <2	Dissolved Phosphorus	EPA 365.1 Compatible[10]
2-6°C, H_2SO_4, pH <2	Total Nitrogen	USGS Alkaline Persulfate[12]

*SFWMD and third-party total iron samples were preserved with nitric acid

PFWS Lakeland Limit of Quantitation and MDL

The PFWS Lakeland data that will be presented in this report comes from the field testing that was performed on-site during the demonstration. In order to perform the testing on location we utilized testing kits that were manufactured by Hach. For several of these kits, Hach provides a quantitation range for the test with the lower end being their quantitation limit. The values for the limit of quantitation for Hach methodologies in use have been listed in Table 4 below.

Table 4: Limit of Detection provided by Hach for the parameters that use their kits and Instrumentation

Analyte	Limit of Detection
Color	Not Provided
Total Iron	0.02
Total Phosphorus	0.010
Dissolved Phosphorus	0.010
Total Nitrogen	0.5

The data presented in this report used the above limits of detection in Table 4. Values have only been reported when they are above the LOQ. Otherwise they have been recorded as not determined (ND).

Due to the usage of LOQ values that were provided by the manufacturer of the testing

[14] EPA Method 200.7, Revision 4.4: Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry, 1994

kits, MDLs were not created for the PFWS Lakeland testing. Using the manufacturers LOQ allowed PFWS Lakeland the confidence of not listing values that were below the capability of the instrumentation. Aside from the methods listed above, that were all tested using Hach procedures, alkalinity was also performed using Standard Methods SM2320B[5] as a reference for procedures.

Handheld Measurements (Temperature, Conductivity, pH, Turbidity)
Each time samples were collected the temperature, conductivity, pH and turbidity were recorded. Conductivity was tested with an Oakton pH 150 handheld meter. Temperature and pH were measured with an Oakton Conductivity 150 handheld meter. Turbidity was measured with a T-100 meter. The FDEP protocols FT1200[7](conductivity), FT1400[11] (temperature), FT1100[9] (pH), and FT1600[13] (turbidity) were consulted for calibration and verification. Conductivity and pH standards were purchased from Thomas Scientific as finished solutions. ASTM Type 1 Reagent grade water from the PFWS Lakeland laboratory was transported in carboys to the site for use as needed.

Inline Measurements (Temperature, Conductivity, pH, Turbidity)
In addition to the handheld testing that was performed via sample collection, several in-line probes were utilized to allow for real-time process control of the system. The probes output data to the custom SCADA system which allowed operators to monitor the data in real time. This information was also set up with alarms were triggered if process parameters drifted out of range. Probes were verified daily with the calibrated handheld instrumentation.

Alkalinity
Standard methods SM2320B[5] was followed when performing alkalinity testing. A glass burette with graduations to 0.1mL was used for volumetric measurement. A dilute solution of H_2SO_4(0.02N) was prepared from analytical grade H_2SO_4 (98%) for use as the titrant. Operators and technicians were trained on both use of indicator (bromocresol green) and pH using a handheld meter for determination of the endpoint.

Color
Standard methods SM2120C[6] (spectrophotometry) was followed when performing the color analysis. The samples were filtered with a 0.45µm PTFE filter prior to analysis. A Hach DR2800 spectrophotometer set to a wavelength of 455nm was used to measure the absorbance from the samples. A calculation method preinstalled in the DR2800 then calculates the color from the absorbance. The color as reported by the spectrophotometer was verified by a platinum-cobalt solution supplied by Hach.

Total Iron
A US EPA approved method for total iron in wastewater using the Hach FerroVer was utilized for testing iron on site. The method is a spectrophotometric analysis. The Hach DR2800 spectrophotometer was set to a wavelength of 510nm. The sample was first pH conditioned with a 10% solution of H_2SO_4. The sample without FerroVer reagent was used to zero the system. After addition of the reagent and after waiting for the reaction to complete the sample was analyzed of the spectrophotometer. A calculation method preinstalled in the DR2800 was used to calculate the concentration of iron in mg/L.

Total Phosphorus
Hach sample kits using an EPA 365.1[10] compatible method were used for testing phosphorus in the field. The method uses heat and an acid persulfate solution to convert all organic material into ortho-phosphorus(reactive). The reactive phosphorus is then reacted with molybdate and antimony to form a complex that has absorbance maxima at 880nm. Samples were volumetrically added to reagent tubes. They were then digested using a Hach DRB200 reactor. Finally, the samples were then analyzed with a Hach DR2800. A PFWS Lakeland calibration curve for the determination of phosphorus concentration(mg/L) has been developed and based on third-party validation testing has a small positive bias in low range testing, meaning that the PFWS total and dissolved phosphorus analyses report slightly higher results than the third-party laboratories. This results largely from a difference in the size of the sample digested in the field and the greater sensitivity of fixed laboratory instrumentation compared to field quality instruments.

Dissolved Phosphorus
The dissolved phosphorus sample was first filtered through a 0.45µm PTFE filter and then tested as listed above in the total phosphorus section.

Total Nitrogen
For total nitrogen testing PFWS used a Hach sample kit that employs the USGS Alkaline Persulfate digestion. The method uses a persulfate digestion to convert all organic nitrogen into nitrate and then react the nitrate with 2,6-dimethylphenol which can then be analyzed spectrophotometrically. The samples are volumetrically added to a reagent test tube which is then placed in a Hach DRB200 reactor which provides the heat for the digestion. The sample is then analyzed with the Hach DR2800 spectrophotometer. A preinstalled method analyzes the sample for absorbance at 345 nm and performs the calculation to calculate mg/L.

Third-Party Methodology

Sample Collection
Pace Analytical was contracted as the third-party laboratory to provide sample analysis for key water quality parameters. They provided coolers with the labeled sample bottles that included the appropriate preservatives. Operators/technicians tasked with collecting this sample flushed sample lines and then filled the provided bottles. Times were recorded and the samples were place in cooler with ice.

Sample Shipment
Once the set of samples was collected and the chain of custody documentation completed, everything was placed in the cooler with ice. The cooler was then shipped via overnight service to Pace Analytical for analysis.

Table 5: Analytical methods, limits of quantitation, minimum detection, and units for Pace

Analyte	Analytical Method	LOQ	MDL	Units
Iron	EPA 200.7[14]	40	9.2	µg/L
Apparent Color	SM2120B[6]	5.0	5.0	Units
Alkalinity	SM2320B[5]	5.0	5.0	mg/L as $CaCO_3$
Total Nitrogen	Calculation from addition of EPA 351.2[15] (Total Kjeldahl Nitrogen) and EPA 353.2[16](NO2/NO3)	0.500	0.086	mg/L
Dissolved Phosphorus	EPA 365.3[17]	0.0040	0.0028	mg/L
Total Phosphorus	EPA 365.3[17]	0.0040	0.0028	mg/L

Third-Party Data
The third-party laboratory submitted all data in the form of reports. These reports have been attached in Appendix B. The naming convention in all the reports is as follows:

- Any sample ID with an A is an inflow sample
- Any sample ID with a B is an outflow sample

The numbers were used to distinguish different time pulls. For example, 1A and 1B are inflow and outflow samples at time point 1 and then 2A and 2B are inflow and outflow samples for time point 2. The date and timestamp in the "Date Collected" field of the report is used to determine when the sample was collected.

In reports 35431591 and 35431596 the dissolved phosphorus concentration reported by the third-party was analytically identical to the total phosphorus. A lack of filtration for these samples is the most likely explanation.

In report 35434387 sample 3A and 3B appeared to be reversed (i.e. the inflow was called the outflow and vice versa). This assessment was made by comparing all analytes and comparing them to previous samples. The third-party was contacted and upon their review could not document that the samples were reversed. These analytical results were considered outliers and removed from reported averages or other calculations.

Split Sampling Methodology
Approximately once a week at each site, SFWMD sent a representative to collect a split sample. A single sample from a flushed line was collected. The sample was then divided into three equal portions, one of which was provided to the SFWMD's representative. The remaining portions of the sample were sent to PFWS Lakeland and the third-party

[15] EPA Method 351.2, Revision 2.0: Determination of Total Kjeldahl Nitrogen by Semi-Automated Colorimetry, 1993
[16] EPA Method 351.2, Revision 2.0: Determination of Nitrate-Nitrite Nitrogen by Semi-Automated Colorimetry, 1993
[17] EPA Method 365.3: Phosphorus, All Forms (Colorimetric, Ascorbic Acid, Two Reagent), 1978

laboratory. The representative for SFWMD managed both the preservation and the chain of custody for the SFWMD sample. The process was completely independent of PFWS.

Summary Result Tables

The data presentation is split into 4 subgroups corresponding to the individual locations. The demonstration operated for approximately two weeks at each site. The demonstration period (Nov. 2018 – Jan. 2019) occurred during the dry season and during a period when the Lake Okeechobee discharge gates were closed. The site was staffed 24-hours per day and 7 days per week. The target flow rate for treatment with this equipment was 2 gpm. Several times per day operators/technicians collected samples for laboratory analysis or to verify process parameters. To clarify, process parameters are measurements that were used to assess operational compliance with process setpoints.

The following table (Table 6) summarizes the performance that was noted during the demonstration at the different locations.

Table 6: Summary of Performance

Location	Start Date	End Date	Mean Inflow TP Conc. (mg/L)	Mean Outflow TP Conc. (mg/L)	TP Removal Rates (mg/L)	Volume Processed (GAL)
DuPuis	11/7/2018	11/21/2018	0.1158	0.0250	0.0908	34538
LaBelle	11/24/2018	12/9/2018	0.086	0.0283	0.0577	38107
S-191 Canal	12/10/2018	12/20/2018	0.2091	0.1252	0.0839	27187
Lake Okeechobee - NE	12/26/2018	1/13/2019	0.1353	0.0527	0.0826	39270

PFWS Lakeland data was utilized to monitor process performance in near real time to ensure compliance with process setpoint parameters and to create an historical archive of performance data. The frequency of testing was established to ensure that process related variances could be corrected as quickly as possible.

To ensure data integrity, PFWS periodically throughout the study period validated the PFWS Lakeland laboratory performance through multiple third-party sample submissions and analysis of split samples that were submitted to the NELAC certified third-party laboratory that provided analytical services for this project.
Quality control for PFWS Lakeland analytical operation was consisted of routine validation

and comparison with third party results, daily calibration of field and laboratory instruments, repeated analysis of standards, blanks and unknown samples. Standards were used to verify instrument calibration. Field instruments were routinely calibrated, and standards utilized for verification of the instrumentation.

Table 7: Summary Data - PFWS Lakeland Analytical – DuPuis - November 8-21

Parameter	Site Name	Mean Measured Value Inflow	Mean Measured Value Outflow	Units	Number of Samples	LOQ
Alkalinity	DuPuis	90	38	ppm as CaCO3	12	ND
Color	DuPuis	151	44	units	12	ND
Conductivity	DuPuis	552	927	µS/cm	36	ND
pH	DuPuis	7.6	8.4	pH	22	ND
Temperature	DuPuis	22.6	22.2	°C	13	ND
Total Iron	DuPuis	0.10	0.03	ppm	10	0.02
Total Nitrogen	DuPuis	1.27	0.95	ppm	11	0.5
Dissolved Phosphorus	DuPuis	0.0411	0.0206	ppm	30	0.010
Total Phosphorus	DuPuis	0.1158	0.0250	ppm	30	0.010
Turbidity	DuPuis	12.9	5.7	NTU	36	ND

The incoming phosphorus concentration was observed to be more variable than at the other testing locations, possibly as a result of recreational activity on the canal. As displayed in Table 7 above alkalinity was decreased by more than half from the inflow to outflow. Color was also reduced by more than half comparing inflow color to outflow color. Turbidity in the inflow had a day to day observed fluctuation of 6.5NTU with an average reduction of 44% after processing. Total nitrogen was decreased by about 25%-30% using the process. The third-party reports (Appendix B) indicate that this nitrogen removal was mainly from organic sources. This conclusion was reached as follows: Total nitrogen is the addition of the concentration of organic nitrogen/ammonia added together with the concentration of inorganic sources (nitrate and nitrite). The third-party lab was able to test for total nitrogen using EPA 351.2[15] Total Kjeldahl

Nitrogen (TKN) (organic nitrogen and ammonia) and EPA 353.2[16] nitrate/nitrite. The data in the reports does not show any significant concentration increase in the inorganic nitrogen. Only the TKN decreases, which leads to the conclusion that removed nitrogen was of an organic form. Further, the samples were analyzed for ammonia (data not displayed) to rule out other potential forms of nitrogen. Future studies would be necessary to determine the ratio of dissolved to particulate organic nitrogen removed. Conductivity was increased by 68% after treatment. This increase is due to treatment process described later in this report. This level is below the Class III Water Standards[1] of 1250 µS/cm. Approximately 70% of the iron was removed comparing inflow to outflow iron residual.

Table 8: Summary Data - PFWS Lakeland Analytical – LaBelle - November 24-December 9.

Parameter	Site Name	Mean Measured Value Inflow	Mean Measured Value Outflow	Units	Number of Samples	LOQ
Alkalinity	LaBelle	106	52	mg/L as CaCO3	41	ND
Color	LaBelle	84	35	units	42	ND
Conductivity	LaBelle	432	816	µS/cm	44	ND
pH	LaBelle	7.8	8.1	pH	42	ND
Temperature	LaBelle	22.6	22.6	°C	41	ND
Total Iron	LaBelle	0.04	0.02	mg/L	41	0.02
Total Nitrogen	LaBelle	1.70	1.50	mg/L	21	0.5
Dissolved Phosphorus	LaBelle	0.0368	0.0136	mg/L	44	0.010
Total Phosphorus	LaBelle	0.0860	0.0283	mg/L	44	0.010
Turbidity	LaBelle	8.5	9.4	NTU	44	ND

As seen in Table 8 above, most of the results at LaBelle were similar those at the DuPuis site. However, the inflow phosphorus concentration was noted to be less variable (±0.024mg/L compared to ±0.067mg/L) at DuPuis. Alkalinity and color were reduced by approximately half after treatment. Inflow turbidity at LaBelle was an average of 34% lower than observed values at DuPuis. Turbidity at this location did not have an observable difference after running through the process. Total nitrogen was also decreased with the treatment producing an average removal of 12%. The average conductivity increased by 384µS/cm. Approximately 50% of the iron was removed.

Table 9: Summary Data - PFWS Lakeland Analytical - S-191 Canal - Dec 10-20.

Parameter	Site Name	Mean Measured Value Inflow	Mean Measured Value Outflow	Units	Number of Samples	LOQ
Alkalinity	S-191 Canal	76	56	mg/L as CaCO3	34	ND
Color	S-191 Canal	154	101	units	35	ND
Conductivity	S-191 Canal	497	1228	µS/cm	35	ND
pH	S-191 Canal	7.7	7.9	pH	35	ND
Temperature	S-191 Canal	20.0	20.2	°C	35	ND
Total Iron	S-191 Canal	0.23	0.15	mg/L	35	0.02
Total Nitrogen	S-191 Canal	1.51	1.44	mg/L	31	0.5
Dissolved Phosphorus	S-191 Canal	0.1771	0.0945	mg/L	35	0.010
Total Phosphorus	S-191 Canal	0.2091	0.1252	mg/L	35	0.010
Turbidity	S-191 Canal	3.2	5.1	NTU	35	ND

Treatment at S-191 provided challenges that were not observed at any of the other locations. The inflow total phosphorus at this location was higher than the other locations(0.2091mg/L) (Table 9). Phosphorus removal was less effective at this location with a reduction of 60%. Other analytes also demonstrated performance inconsistent with previous results. For example, the alkalinity drop was only 26% after the treatment versus the 50% observed at other locations. The color experienced a 34% decrease at this location. Due to stagnant conditions at the site inflow turbidity was the lowest observed with an average of 3.2. Total nitrogen removal also decreased, producing an average removal of 5%. The average conductivity at this location was higher due to efforts to define optimum operating parameters. It is believed that this location contained higher than normal levels of residual surfactants. The water exhibited behavior consistent with significant amounts of detergent (surfactant) as it frothed and foamed unlike the previous locations. Samples from this location have been submitted for more extensive analysis including gas chromatography, x-ray diffraction and scanning electron microscopy to further understand this anomalous behavior. The above techniques will be used to analyze the precipitation solids for surface formation and composition. The current hypothesis is that some component present in this water, is inhibiting the formation of the desired precipitation product. By analyzing the surface structure and composition further insight into the mechanism of this interference is anticipated.

Table 10: Summary Data - PFWS Lakeland Analytical - Lake Okeechobee, NE - December 26-January 13.

Parameter	Site Name	Mean Measured Value Inflow	Mean Measured Value Outflow	Units	Number of Samples	LOQ
Alkalinity	Lake Okeechobee - NE	57	30	mg/L as CaCO3	57	ND
Color	Lake Okeechobee - NE	107	50	Units	58	ND
Conductivity	Lake Okeechobee - NE	432	880	µS/cm	58	ND
pH	Lake Okeechobee - NE	8.2	8.1	pH	58	ND
Temperature	Lake Okeechobee - NE	20.4	20.5	°C	58	ND
Total Iron	Lake Okeechobee - NE	0.12	0.04	mg/L	57	0.02
Total Nitrogen	Lake Okeechobee - NE	1.47	1.15	mg/L	57	0.5
Dissolved Phosphorus	Lake Okeechobee - NE	0.0376	0.0256	mg/L	58	0.010
Total Phosphorus	Lake Okeechobee - NE	0.1277	0.0438	mg/L	58	0.010
Turbidity	Lake Okeechobee - NE	18.3	8.5	NTU	58	ND

The results at Lake Okeechobee – NE were similar to those at the DuPuis and LaBelle locations. After treatment the alkalinity decreased by 47% and color by 53%. Inflow turbidity at Lake Okeechobee -NE had the highest turbidity observed for all the testing locations. However, it observed the second largest decrease in turbidity during the treatment process (54%). Total nitrogen was also decreased with the treatment producing an average removal of 22%. Average conductivity between the inflow and outflow was increased from 432 to 880 µS/cm. The process removed 67% of the iron.

Table 11: Average Data for PFWS Lakeland Analytical - DuPuis, LaBelle, and Lake Okeechobee - NE.

Parameter	Site Name	Mean Measured Value Inflow	Mean Measured Value Outflow	Units	Number of Samples	LOQ
Alkalinity	Combination	79	39	mg/L as $CaCO3$	110	ND
Color	Combination	110	46	units	112	ND
Conductivity	Combination	463.6	871.7	µS/cm	138	ND
pH	Combination	7.9	8.2	pH	122	ND
Temperature	Combination	21.5	21.4	°C	112	ND
Total Iron	Combination	0.09	0.03	mg/L	112	0.02
Total Nitrogen	Combination	1.50	1.21	mg/L	89	0.5
Dissolved Phosphorus	Combination	0.0399	0.0204	mg/L	132	0.010
Total Phosphorus	Combination	0.1145	0.0381	mg/L	132	0.010
Turbidity	Combination	13.8	8.3	NTU	138	ND

Table 11 above represents a summary of the overall average analytical results at locations 1, 2, and 4. Site 3 was not included due to conditions noted elsewhere.

Third-Party Summary Data

During the demonstration samples were collected and shipped to Pace Analytical Laboratories for analysis. The table below (Table 12) summarizes the average data generated by the third-party testing laboratory for all data reported by the third-party laboratory.

Table 12: Third-Party (Pace) Summary Data - all site locations

Parameter	Site Name	Mean Measured Value Inflow	Mean Measured Value Outflow	Units	Number of Samples	LOQ
Alkalinity	Combination	110	46	mg/L as CaCO3	27	5.0
Color	Combination	53	23	units	27	5.0
pH	Combination	8.0	8.1	pH	27	ND
Total Iron	Combination	0.381	0.094	mg/L	21	0.04
Total Nitrogen	Combination	1.3	0.90	mg/L	33	0.5
Dissolved Phosphorus	Combination	0.067	0.019	mg/L	33	0.004
Total Phosphorus	Combination	0.106	0.030	mg/L	33	0.004

Split Sample Comparison Summary

Throughout the demonstration SFWMD would periodically visit the site and collect samples that were divided and analyzed by multiple parties. The remainder of the samples would then be submitted to both PFWS Lakeland and third-party (Pace) such that each laboratory was analyzing a split from an identical sample. The tables below (Table 13-Table 17) list the analytical data reported by PFWS and Pace Analytical. Whenever possible data from SFWMD has been added to the table for comparison.

Table 13: Sample Date-11/15/2018

		PFWS Lakeland		Pace		SFWMD	
Parameter	**Units**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**
Alkalinity	mg/L as CaCO3	112	48	Not Tested	Not Tested	Not Tested	Not Tested
Color	units	38	19	Not Tested	Not Tested	Not Tested	Not Tested
pH	pH	6.8	8.9	Not Tested	Not Tested	Not Tested	Not Tested
Total Iron	mg/L	0.17	0.02	Not Tested	Not Tested	Not Tested	0.067
Total Nitrogen	mg/L	1.30	0.89	1.20	0.73	Not Tested	Not Tested
Dissolved Phosphorus	mg/L	0.033	0.015	0.150	0.048	Not Tested	Not Tested
Total Phosphorus	mg/L	0.130	0.030	0.150	0.030	Not Tested	0.024

Table 14: Sample Date-11/19/2018

		PFWS Lakeland		Pace		SFWMD	
Parameter	**Units**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**
Alkalinity	mg/L as CaCO3	106	40	Not Tested	Not Tested	Not Tested	Not Tested
Color	units	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
pH	pH	7.5	8.1	Not Tested	Not Tested	Not Tested	Not Tested
Total Iron	mg/L	0.16	0.07	Not Tested	Not Tested	0.207	0.081
Total Nitrogen	mg/L	1.21	0.78	0.95	0.64	Not Tested	Not Tested
Dissolved Phosphorus	mg/L	0.040	0.024	0.038	0.016	Not Tested	Not Tested
Total Phosphorus	mg/L	0.103	0.031	0.110	0.024	0.080	0.025

Table 15: Sample Date-11/27/2018

		PFWS Lakeland		Pace		SFWMD	
Parameter	**Units**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**
Alkalinity	mg/L as CaCO3	72	36	108	51	Not Tested	Not Tested
Color	units	48	25	60	25	Not Tested	Not Tested
pH	pH	7.4	8.2	7.9	8.1	Not Tested	Not Tested
Total Iron	mg/L	0.06	0.03	0.11	0.03	0.148	0.040
Total Nitrogen	mg/L	Not Tested	Not Tested	1.40	1.10	Not Tested	Not Tested
Dissolved Phosphorus	mg/L	0.035	0.013	0.048	0.008	Not Tested	Not Tested
Total Phosphorus	mg/L	0.064	0.026	0.068	0.024	0.068	0.022

Table 16: Sample Date-12/04/2018

		PFWS Lakeland		Pace		SFWMD	
Parameter	**Units**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**
Alkalinity	mg/L as CaCO3	70	32	109	53	Not Tested	Not Tested
Color	units	69	38	60	20	Not Tested	Not Tested
pH	pH	Not Tested	Not Tested	8.0	8.1	Not Tested	Not Tested
Total Iron	mg/L	0.01	0.01	0.13	0.02	0.250	0.017
Total Nitrogen	mg/L	0.93	0.67	1.30	0.91	Not Tested	Not Tested
Dissolved Phosphorus	mg/L	0.044	0.023	0.033	0.015	Not Tested	Not Tested
Total Phosphorus	mg/L	0.082	0.027	0.094	0.022	0.097	0.021

Table 17: Sample Date-1/10/2019

		PFWS Lakeland		Pace		SFWMD	
Parameter	**Units**	**Inflow**	**Outflow**	**Inflow**	**Outflow**	**Inflow**	**Outflow**
Alkalinity	mg/L as CaCO3	54	28	107	42	Not Tested	Not Tested
Color	units	63	11	70	30	Not Tested	Not Tested
pH	pH	8.3	7.5	8.2	7.7	Not Tested	Not Tested
Total Iron	mg/L	0.06	0.05	0.62	0.11	Not Tested	Not Tested
Total Nitrogen	mg/L	1.01	0.79	3.2	0.87	Not Tested	Not Tested
Dissolved Phosphorus	mg/L	0.019	<LOD	0.042	0.018	Not Tested	Not Tested
Total Phosphorus	mg/L	0.092	<LOD	0.130	0.029	Not Tested	Not Tested

Note: SFWMD did send a representative out and a sample was collected however we did not receive the results in time to include in this report.

PFWS Lakeland Validation Testing

As a component of the PWFS quality program, split samples were collected throughout the demonstration. These identical samples were then analyzed by both the third-party laboratory and the PFWS field-testing laboratory. The average results are displayed in Table 18 below.

Table 18: Comparison of independent data to PFWS Lakeland testing

Parameter	Mean Pace Inflow	Mean Pace Outflow	Mean Lakeland Inflow	Mean Lakeland Outflow	Units
Alkalinity	110	46	79	39	mg/L as CaCO3
Color	53	23	110	46	units
pH	8.0	8.1	7.9	8.2	pH
Total Iron	0.381	0.094	0.09	0.03	mg/L
Total Nitrogen	1.3	0.9	1.50	1.21	mg/L
Dissolved Phosphorus	0.067	0.019	0.0399	0.0204	mg/L
Total Phosphorus	0.106	0.030	0.1145	0.0381	mg/L

The data in Table 18 identifies some differences in results between laboratories. These differences are the result of different test methodologies which report values that are intended for comparison only within the same method. For example, color, when analyzed by the third-party utilizes a visual methodology that relies on an operator's interpretation of color. The Hach methodology utilized by PFWS Lakeland relies on a spectrophotometric determination of color that is reported in standardized platinum-cobalt units. These two systems are not intended for direct comparison and only a comparison between samples using the same method should be made. However, it should be noted that in the case of color as shown in Table 18, that both laboratories report a 50% reduction in color even though the color determination was made with different methods and the actual values are different. Other parameters that use different methodologies between the two labs include total iron and total nitrogen.

The iron concentrations in the third-party test methodologies are generally higher than the PFWS Lakeland testing. This is due to the third-party test methodology using a full-scale digestion vs the test method used by PFWS Lakeland which presumes that the majority of iron in the water can be converted to dissolved with a pH adjustment. As an absolute number, the third-party data should be considered the more reliable data as the PFWS Lakeland method is a "field test". Regardless of the analytical source, the demonstration of approximately 70% iron removal in

Table 18 (higher inflow than outflow) remains consistent in both third-party and PFWS Lakeland testing.

Alkalinity was another source of significant difference between the third-party results and PFWS Lakeland. The PFWS Lakeland method performed utilizes a titration method with indicators for the endpoint. This test was conducted by multiple individuals and held consistent values over the period of the trial. As with the iron and color regardless of the analytical source the percentage drop for both third party and PFWS Lakeland between the inflow and outflow was approximately 50%

While the data for all analytes has been provided for completeness the primary importance has been ensuring that the testing method for phosphorus was accurate and reliable in the field as testing in the field is imperative to ensure the rapid return of results and timely monitoring of process performance. As can be seen in Figure 10 below the total phosphorus methodologies correlate well with a difference of 8% in the inflow between the two test methodologies. Please note that the discrepancy in concentration as displayed in Figure 11 for the dissolved phosphorus on dates 11/13/18, 11/14/18, 11/15/18 was most likely due to lack of filtration. When comparing the third-party dissolved phosphorus to the third-party total phosphorus for those days the results are analytically identical which is highly unlikely.

Total nitrogen, while utilizing different methodologies correlated well as can be seen in Figure 9. The analytical method used by PFWS Lakeland demonstrated an approximately 20-30% positive bias when compared to the analytical method results from the third-party.

During the Lake Okeechobee -NE testing, the field-testing spectrophotometer malfunctioned and potentially impacted analysis of Color, Total Phosphorus, and Dissolved Phosphorus. The dates in question for this were January 6th, 7th, and 8th. The sample retains (backup samples) for these samples were retested back in Lakeland and that data is presented in the graphs below.

Figure 6-Alkalinity Testing

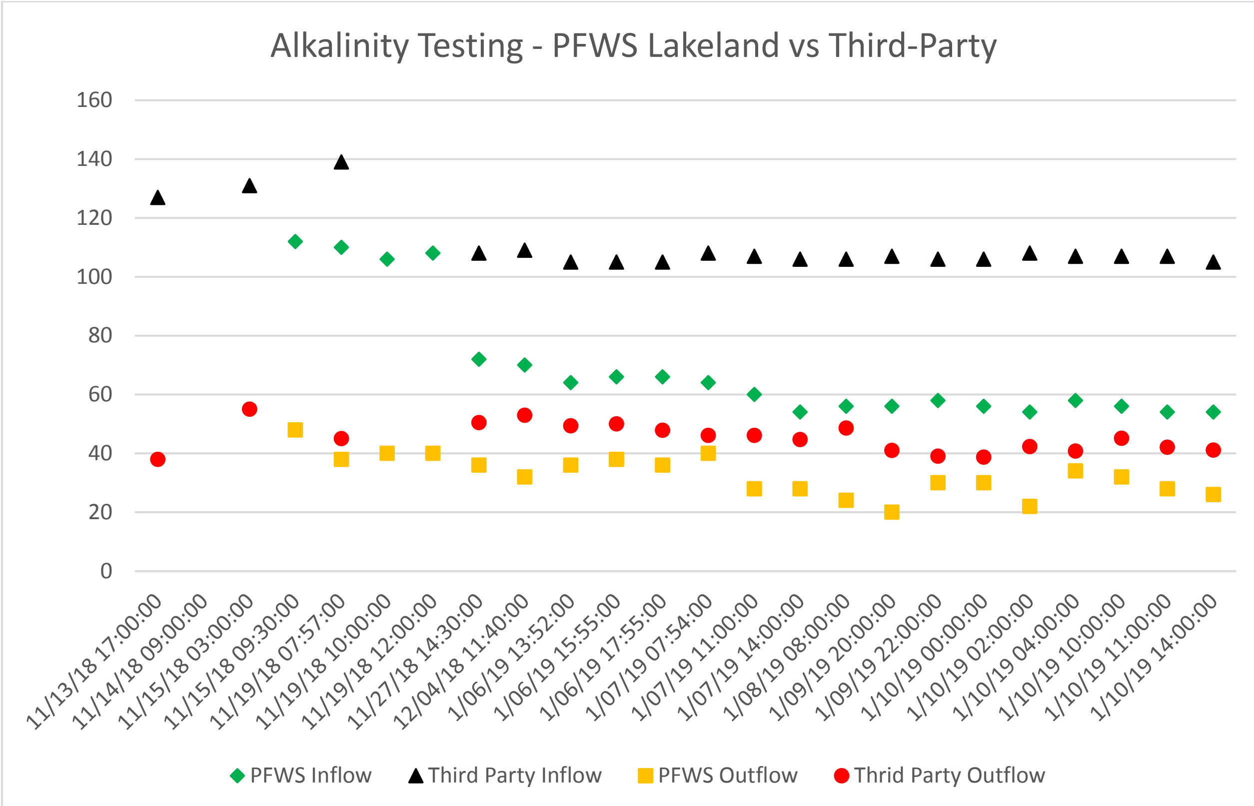


Figure 7-Color Testing

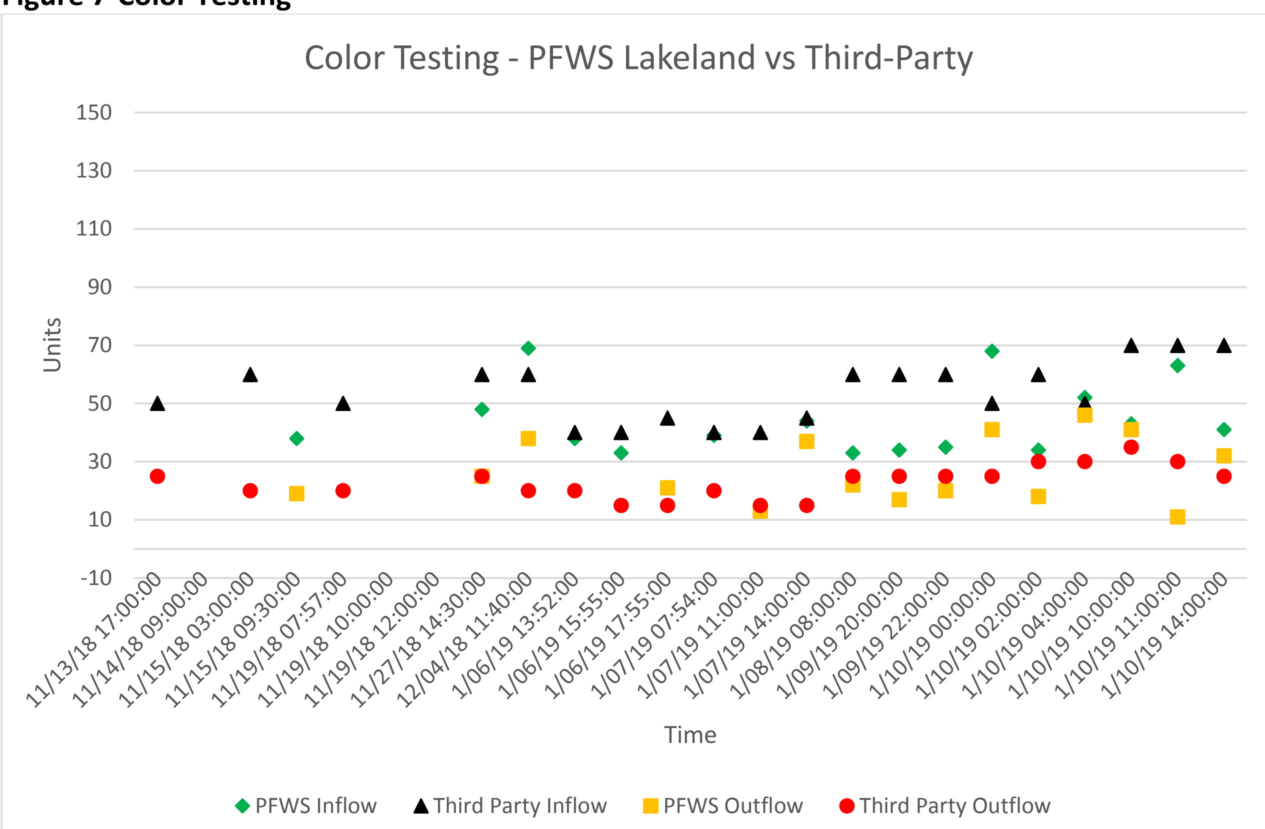


Figure 8-Total Iron Testing

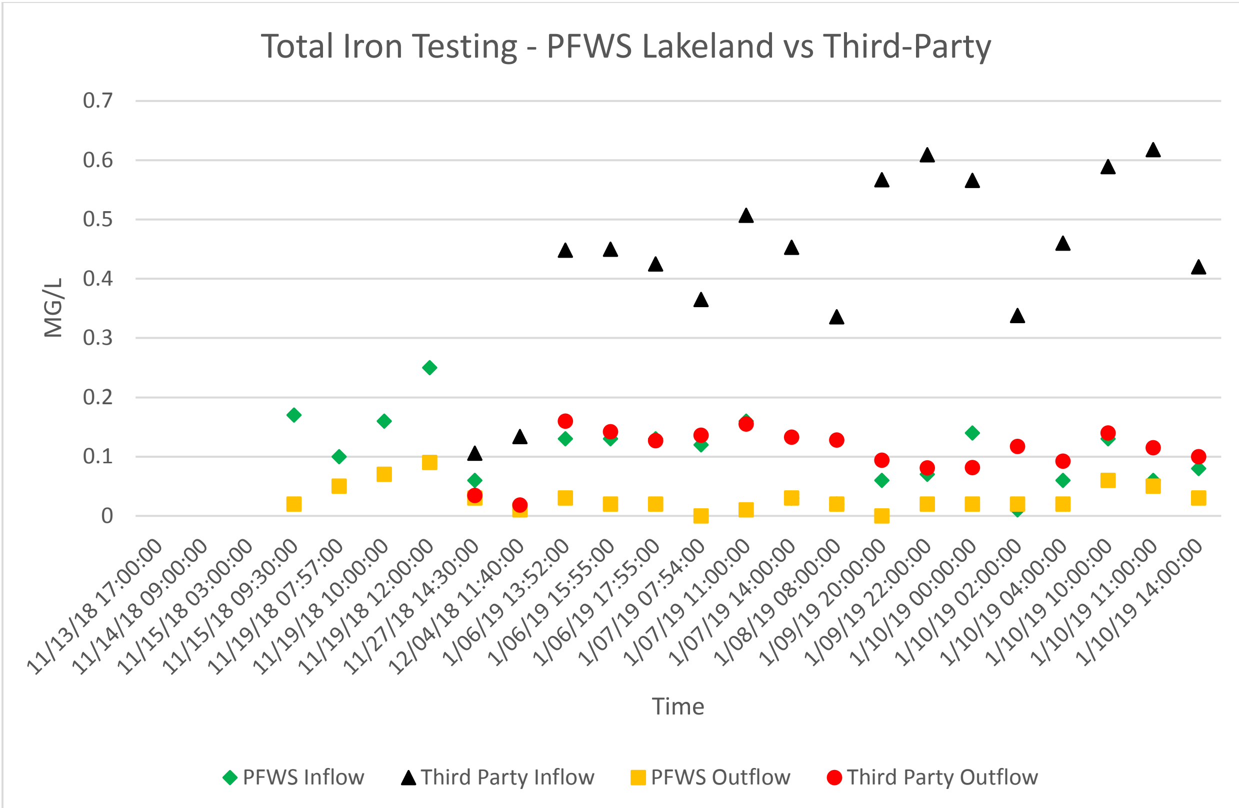


Figure 9-Total Nitrogen Testing

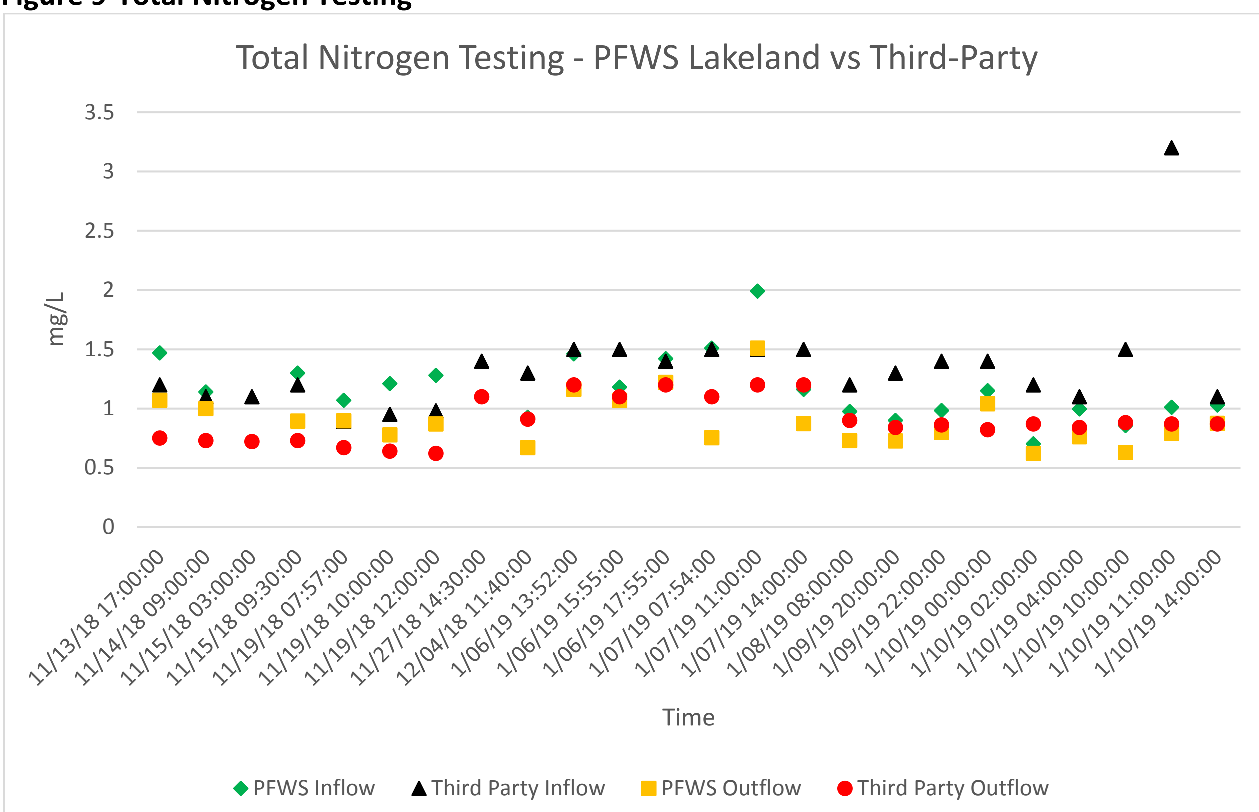


Figure 10-Total Phosphorus Testing

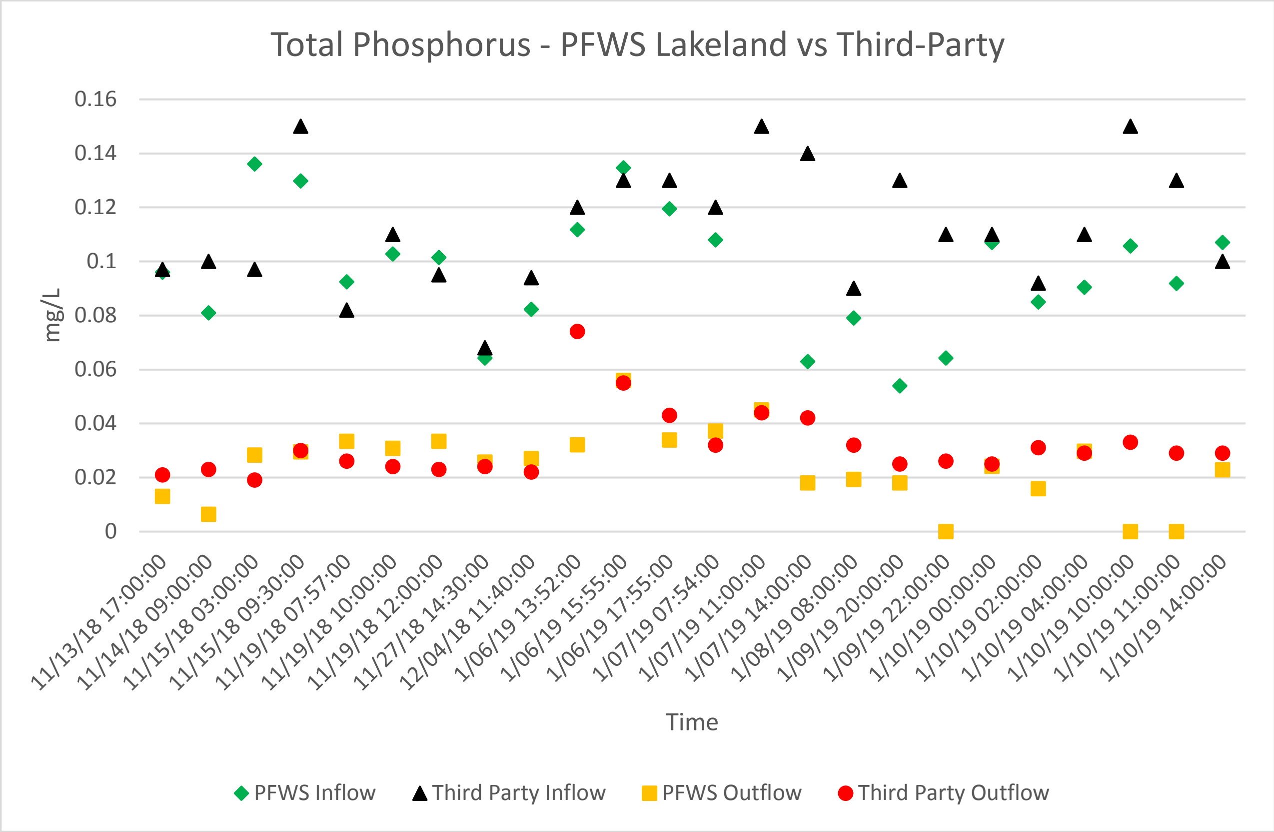
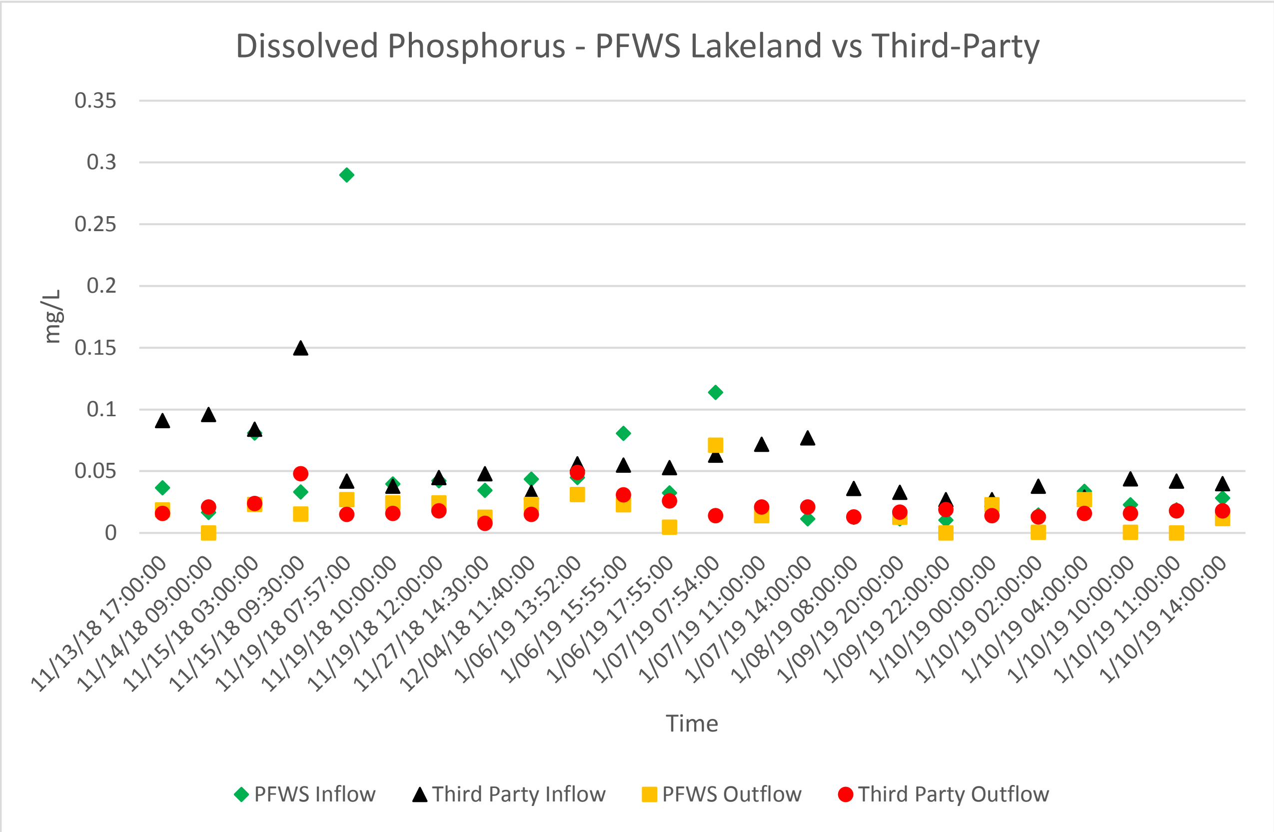


Figure 11-Dissolved Phosphorus Testing



Summary of Flows/SCADA System

Table 19: Summary of Flow

Site Name	Mean Flow Rate (gpm)	Number of Points	Total Gallons Processed	Uptime Percentage
DuPuis	1.8	5714	34538	90.8
LaBelle	1.9	5896	38107	95.6
S-191 Canal	1.9	5863	27187	96.1
Lake Okeechobee - NE	1.9	11492	39270	94.6

Table 19 above lists the average flow rate along with the total gallons recorded by the totalizer. The number of points refers to the number of values recorded by the SCADA system during operations.

The uptime percentage listed in the summary of performance table gives a quick metric to assess the consistency of the running process. To determine this value, data from the SCADA system, which recorded instantaneous flow rates every 5 minutes was used. While data points were recorded at 5-minute intervals the SCADA system was always monitoring to ensure that the flow rate was consistent. The following Figures 12-15 illustrate this by displaying a visual representation of the flow over time. The flow target was 2 GPM and the process oscillated around that flow. Zero GPM marked when the system flow was turned off and then the other points were as the system was in the process of reaching steady state.

Figure 12-DuPuis Process Flow Rates

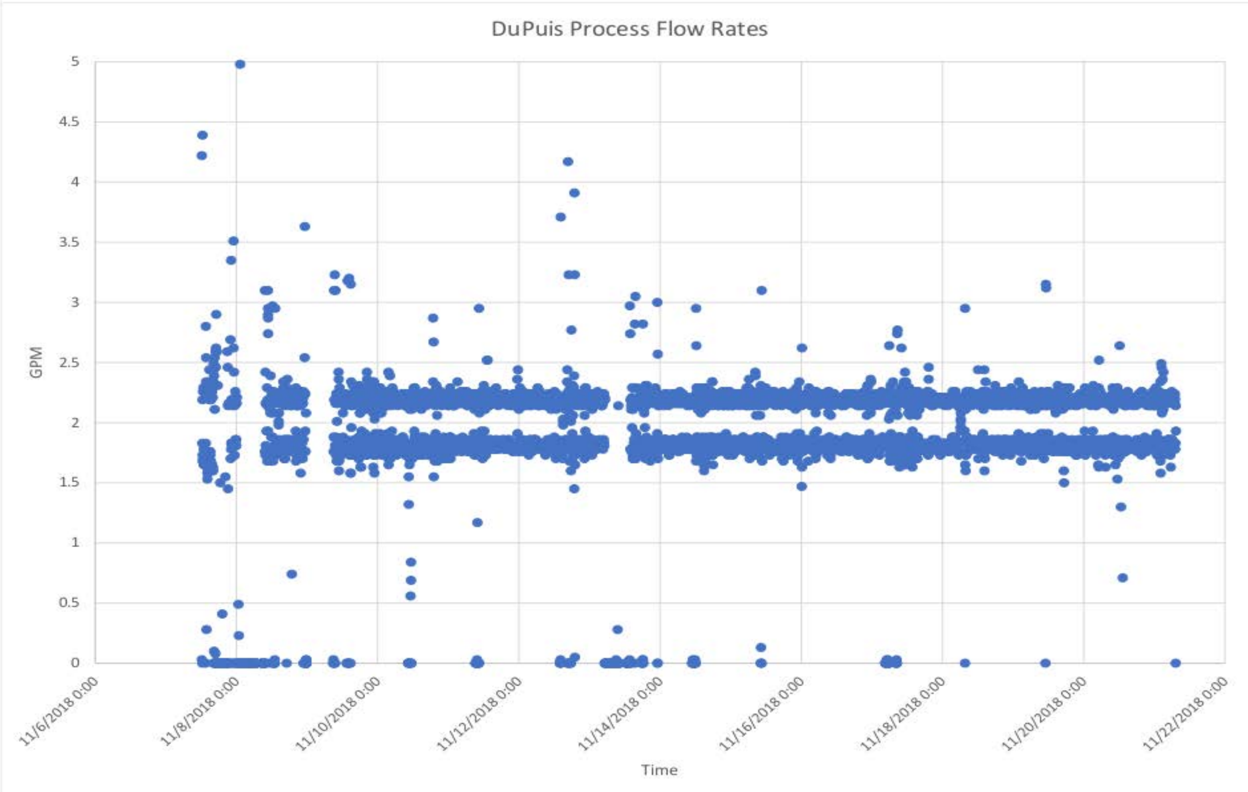


Figure 13-LaBelle Process Flow Rates

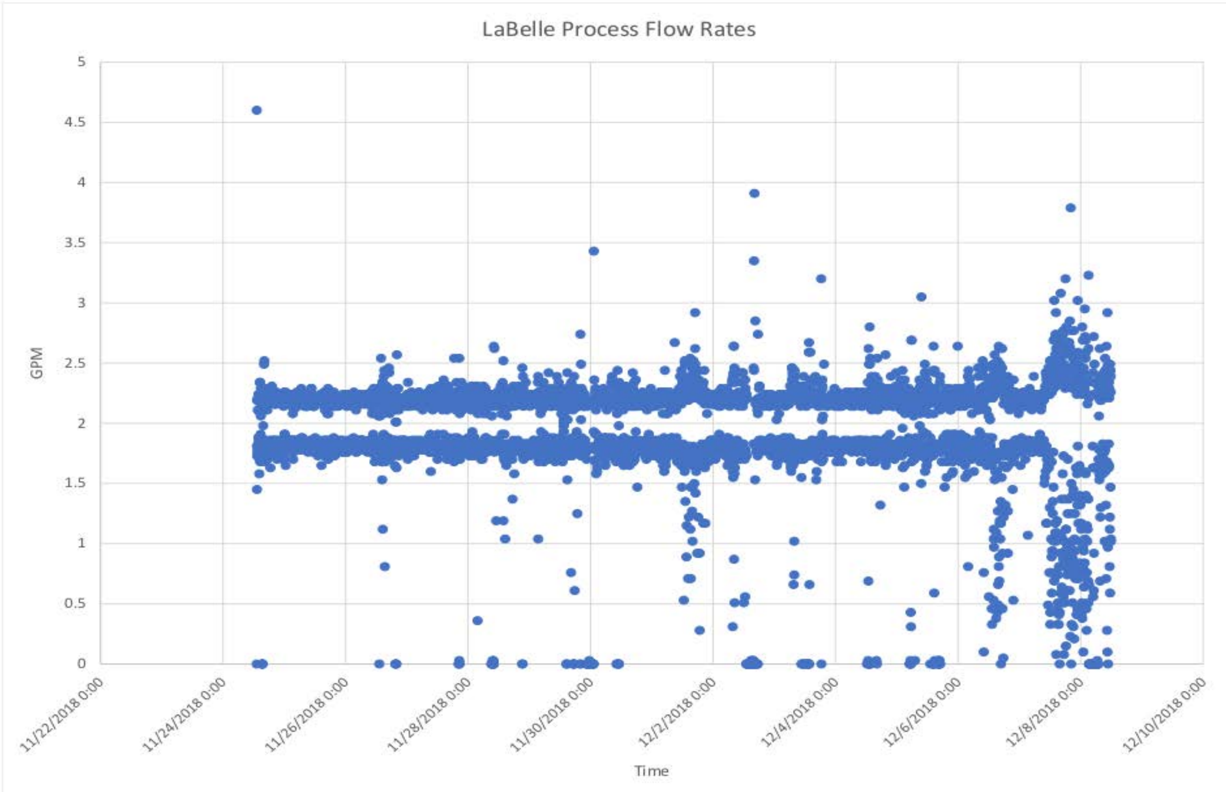


Figure 14- S-191 Canal Process Flow Rates

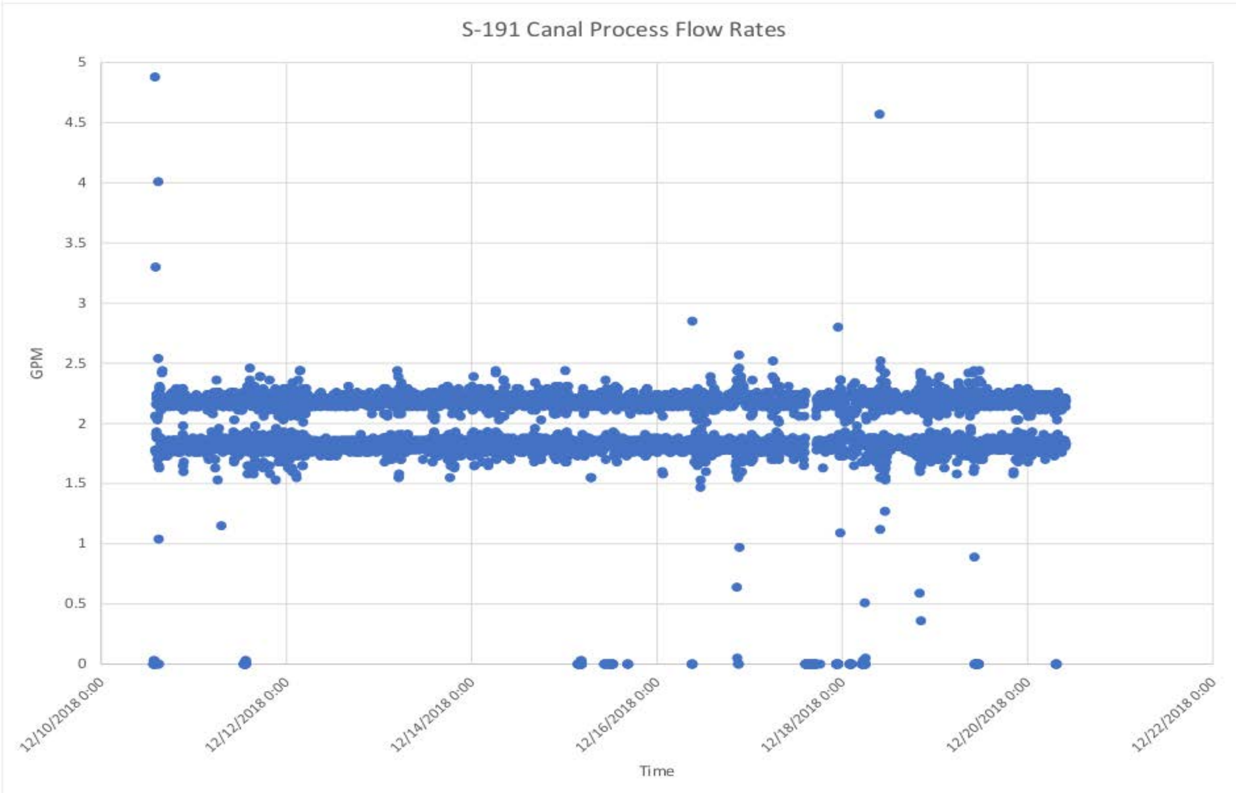
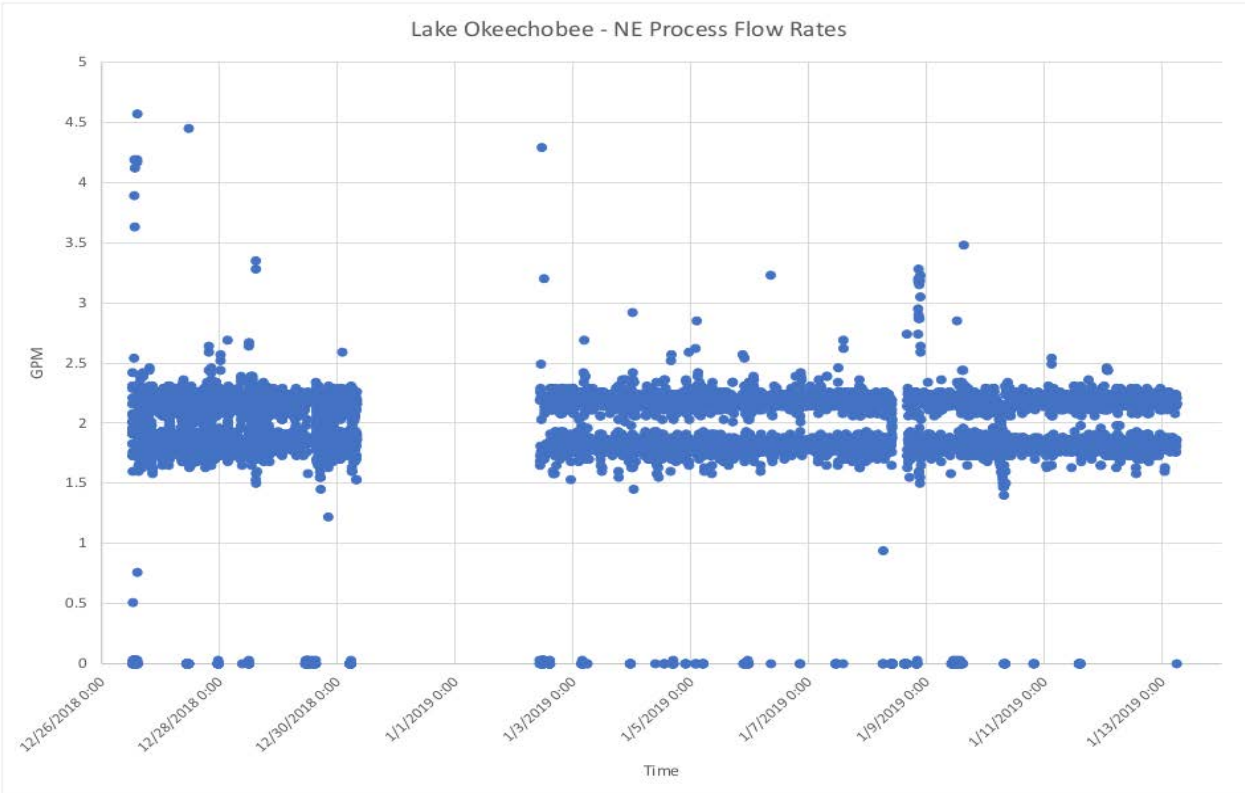


Figure 15- Lake Okeechobee-NE Process Flow Rates



Note: The gap in the flow data represents the New Year's holiday.

Recommendations for Improving the System Outflow

In this scope item, PFWS was asked to address specific concerns about the addition of iron. During all Okeechobee related testing, no compounds containing iron were utilized, however, in previous demonstration studies, PFWS utilized an iron-based oxidant that increased the iron residual in the water somewhat yet remained under Class III limitations for this species. The water locations utilized in this study contained somewhat higher levels of soluble reactive phosphorus than previous locations and as such, the process configuration utilized during this study did not require the use of an iron-based oxidation step to achieve the Phosphorus reduction results reported herein. As the results indicate, background Iron in the water at the locations tested was reduced by as much as 70% (Table 18).

Facility Size Discussion

Facility size is truly a site-specific determination relying on the history of flows and concentrations at a given location. Statistical models are utilized to assist in facility size determinations. In the confidential document section of this report, PFWS has outlined a specific strategy for a Regional Concept. In general, however, treatment costs are inversely proportional to the phosphorus concentration, that is, the higher the phosphorus concentration, the lower the unit cost of treatment. Further, under the PFWS model, the removal cost will be contractually specified.

Long Term Running Costs

The PFWS Demonstration Equipment is not designed for long term (more than a few months) continuous or commercial operations. It was designed as an easily configurable rolling laboratory for the specific purpose of providing a rapid determination of applicability of the technology to specific water conditions and to gather design criteria for commercial scale design volumes. As such, any estimate of running costs based on the operation of the demonstration equipment would not be applicable to commercial scale equipment. For example, the demonstration equipment requires essentially the same number of operating and support personnel as would a commercial scale facility removing orders of magnitude more phosphorus. In addition, the PFWS payment model contractually specifies the total removal cost incurred by the SFWMD and eliminates any risk of escalation in a commercial installation.

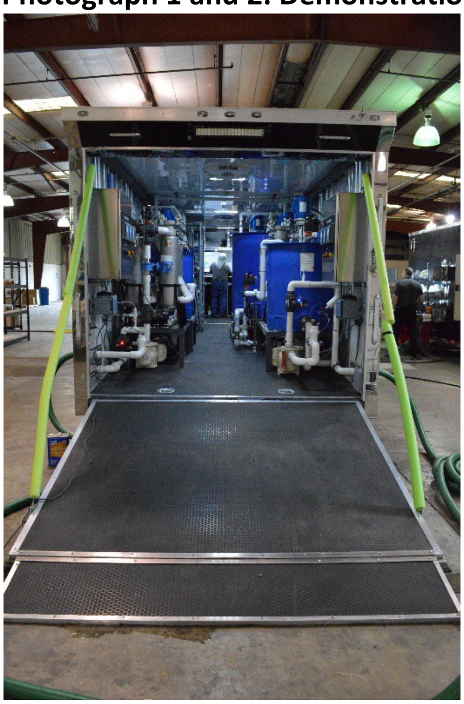
Demonstration Equipment

The PFWS mobile demonstration equipment was constructed inside a 38' triple axel trailer to facilitate ease of movement and testing at multiple locations. A similarly sized support equipment trailer was also constructed to house laboratory, wash down water and supply storage.

Each device was constructed to act as a secondary containment vessel in the event of a chemical spill. Cooling and ventilation are managed by separate dedicated units.

The equipment supplied for the demonstration was a custom designed and fabricated control system unique to the PFWS process. Each piece of process equipment, flow meters, pressure transducers, valve positions, along with process variable like flow, pH, pump speed, turbidity, and pH were monitored continuously, and the value recorded every 2 seconds. In addition, the process equipment was configured in such a way so that variables such as oxidation time and dosage could be evaluated. Flow recordings were observed using a Proline Promag 10W Electromagnetic flow meter. The readings from this meter were then totaled using a totalizer. This data signals were communicated by the SCADA system in place and stored both locally and remotely in a Rockwell Historian Database.

Photograph 1 and 2: Demonstration Equipment looking back to front (PFWS Internal Photo)



Photograph 7: Demonstration Equipment-Large Media columns(l), and small (r) (PFWS Internal Photo)

Confidential Information Notice

The pages following this document are hereby designated and Proprietary, Confidential or Trade Secret information that is the exclusive property of Phosphorus Free Water Solutions, LLC. This Confidential information consists of four pages and is exempt from public disclosure pursuant to the following statutes.

PFWS's Proposal includes a novel and proprietary treatment process, process design and process elements including various treatment feedstocks dosed in various amounts, strengths and sequences ("The Process"). The Process and/ or individual elements therein is presently under the confidential patent pending review process (**35 U.S.C. 122**) before the US Patent and Trademark Office in multiple patent applications, including but not limited to US Patent Application numbers 62/566,865, 62/566,858, 62/566,867, 62/724,925, 4793.005PRV, 4793.006PRV and 4793.008PRV. Further, additional Process improvements and Process elements are under investigation and processing for patent filing protection with the US Patent and Trademark Office. As such, The Process meets the definition as provided for in FS 812.081 as a Trade Secret. Therefore, information regarding The Process (other than that voluntary disclosed herein without request for Confidential Treatment) is exempt from the Florida Public Records Act, pursuant to **FS 812.081**, and **FS 815.045** respectively. Accordingly, PFWS requests Confidential Treatment for all Process information identified herein as Confidential or Confidential Trade Secret. PFWS has undertaken a thorough review of The Process to minimize the scope of information requiring Confidential Treatment.

Further, any PFWS or related party financial information submitted for evaluation by the district is specifically exempt under **FS 119.071** and PFWS respectfully requests such information be afforded Confidential Treatment to the extent submitted and as afforded under **FS 119.071**.

CONFIDENTIAL INFORMATION REDACTED

CONFIDENTIAL INFORMATION REDACTED

CONFIDENTIAL INFORMATION REDACTED

CONFIDENTIAL INFORMATION REDACTED

END OF PROPRIETARY, CONFIDENTIAL AND TRADE SECRET INFORMATION

Citation References

1) FAC-Ch 62-302 – Florida Water Quality Standards (2010). Retrieved from https://www.flrules.org/gateway/ChapterHome.asp?Chapter=62-302

2) Phosphorus Free Water Solutions. (2017). Lake Apopka Dredging, Spoil Management and Water Treatment Project Final Report-Contract 28028.

3) South Florida Water Management District. (2019). *2019 South Florida Environmental Report.* Retrieved from https://www.sfwmd.gov/science-data/scientific-publications-sfer

4) Sano, D., Hodges, A., & Degner, R. (2005, November). Economic Analysis of Water Treatments for Phosphorus Removal in Florida. *UF/IFAS Food and Resource Economics Department, FE* (576).

5) E.W. Rice, R.B. Baird, A.D. Eaton, Standard Methods for the Examination of Water and Wastewater (Online) 2320B Alkalinity Titration Method pp1-3

6) E.W. Rice, R.B. Baird, A.D. Eaton, Standard Methods for the Examination of Water and Wastewater (Online) 2120 Color pp2-1 - 2-7

7) FDEP, FT 1200 Field Measurement of Specific Conductance (Conductivity) 2017

8) Hach, USEPA FerroVer Method, Total Iron Hach Method 8008 DOC316.53.01053 pp1-7

9) FDEP, FT 1100 Field Measurement of Hydrogen Ion Activity (pH) 2017

10) EPA Method 365.1, Revision 2.0: Determination of Phosphorus by Semi-Automated Colorimetry, 1993

11) FDEP, FT 1400 Field Measurement of Temperature 2017

12) USGS, Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Evaluation of Alkaline Persulfate Digestion as an Alternative to Kjeldahl Digestion for Determination of Total and Dissolved Nitrogen and Phosphorus in Water, Water-Resources Investigations Report 03-4174 2003 pp 1-33

13) FDEP, FT 1600 Field Measurement of Turbidity 2017

14) EPA Method 200.7, Revision 4.4: Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry, 1994

15) EPA Method 351.2, Revision 2.0: Determination of Total Kjeldahl Nitrogen by Semi-Automated Colorimetry, 1993

16) EPA Method 353.2, Revision 2.0: Determination of Nitrate-Nitrite Nitrogen by Semi-Automated Colorimetry, 1993

17) EPA Method 365.3: Phosphorus, All Forms (Colorimetric, Ascorbic Acid, Two Reagent), 1978